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The Journal of HEREDITY

A monthly publication devoted to Plant Breeding Animal Breeding and Eugenics

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JUNE, 1923

SAVING THE SIX-NIPPLED BREED
ALEXANDER GRAHAM BELL

DEFECTIVE SEEDS IN MAIZE
P. C. MANGELSDORF

THE RELATIONS OF CYTOLOGY AND GENETICS
P. W. WHITING

ALLEGHENY COLLEGE BIRTH RATE
H. R. HUNT

ENDOSPERM DEFECTS IN MAIZE
E. W. LINDSTROM

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Volume XIV Number 3

IN FUTURE NUMBERS

Chromosomes in Drosophila, two papers by Charles W. Metz and Mildred S. Moses, summarizing what is now known about the carriers of heredity in the fruit fly and its relatives.

Biology in Human Progress, by O. F. Cook. Is civilization subject to fixed cycles of growth and decay, or can the destructive forces be analyzed and their action arrested by the application of biological principles to human affairs?

Naked Oats, by T. R. Stanton. The story of a variety that has been a boon to dishonest seedsmen for a generation.

Freshman Matrimonial Ideals, by Robert T. Hance. The obverse, or rather the reverse of the usually gloomy result of inquiring into the college birth-rate, perhaps because prospective families are considered rather than actual ones.

Age and Area, by Hugo de Vries. Are the most widely spread species the oldest?

Intersexes in Nematodes, by G. Steiner. Few people know what a nematode is, let alone what it looks like. We hope that this article will serve as an introduction to one group of this interesting but little known branch of life.

Inheritance of Spotting in Holstein Cattle, by L. C. Dunn, H. F. Webb, and M. Schneider. How much of the variation in the amount of spotting seen in this popular breed is hereditary?

The

Journal of Heredity

VOL. XIV, No. 3 JUNE, 1923

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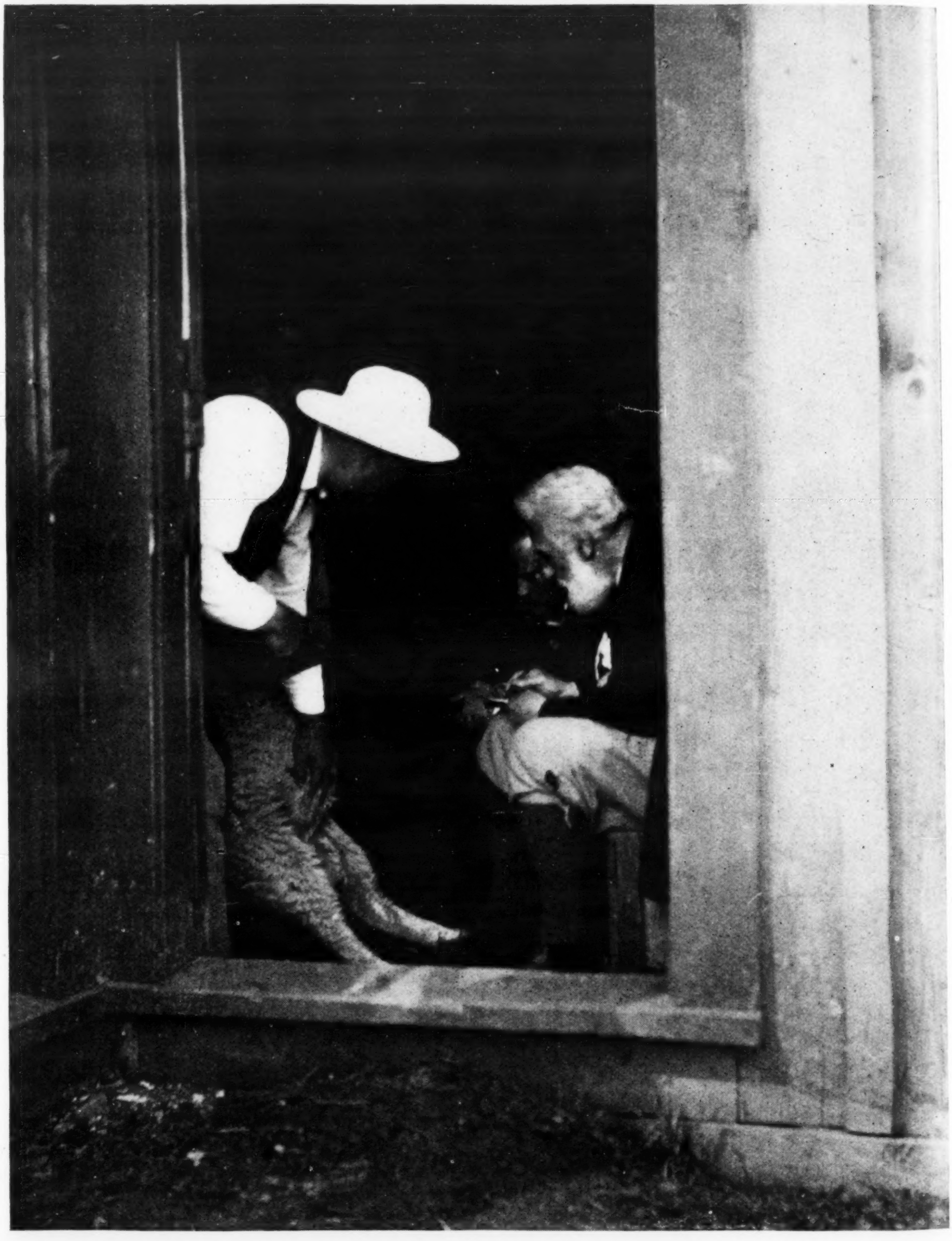


ALEXANDER GRAHAM BELL EXAMINING THE NIPPLES OF ONE OF HIS MULTI-NIPPLED SHEEP

It is remarkable what a place the sheep house had in Mr. Bell's life. In it were used his inventions for weighing and feeding and marking his multi-nippled flock. The news of the birth of the lambs in it was wired to him every spring, no matter where he was. His conviction that the forces of heredity were among the greatest of all forces was as firm as his conviction that the vibrations of the human voice could be transmitted electrically and that the aerial highway overhead would be traversed by man. It is significant that those eyes which could see so deeply into things should have made their last observations in this sheep house. Dr. Grenfell was several times a visitor at Beinn Bhreagh on his way to Labrador. He is here shown sitting on a box beside Dr. Bell. Photograph by Gilbert Grosvenor.

SAVING THE SIX-NIPPLED BREED

ALEXANDER GRAHAM BELL

Mr. Bell's Last Contribution to Science, with An Introduction by Mrs. Bell

UNDER this title Dr. Alexander Graham Bell in June of this year [1922] dictated for preservation in his note-books the last of his summaries of his breed of "Multi-nippled Sheep" which for the past few years he had been in the habit of making every spring.

Whether he had any feeling that each such summary might be his last report on his long-continued sheep experiments does not appear. He never said so. But he was one of those unhurried souls who are "Prepared to die today, but live as if sure of a hundred years for work."

Behind this title lies a whole romance as yet untold, full of dramatic incidents epitomic of Mr. Bell's own character.

As this sheep experiment was one of the last, so it was one of the first of the many investigations in which Mr. Bell engaged while living on Cape Breton Island, and a brief account of its beginning may possibly prove interesting.

In the year 1886 Mr. and Mrs. Bell brought their two little girls to Baddeck, having determined to make their summer home on the island.

They found a tiny deserted cottage, sufficiently far from the village, and near the water's edge to satisfy their requirements for the time. The cottage had no furniture except a dining-table, and little could be bought in the village, so the family themselves made most of what they needed, and slept on bags stuffed with hay.

To this primitive, but very happy home, Mr. Bell one day brought a little lamb. It soon became part of the family circle, following the children wherever they went, in and out of the house. When the time came to leave for the winter the children would not hear of giving away their pet, so arrangements were made for its care through the winter. The next summer when the family returned, *two* sheep, the mother sheep and her little lamb, greeted them.

But why only one lamb?

A progeny of nineteen was no uncommon event in a pig's family. Even dogs generally had as many as six at a birth, while twin lambs were rare, and quadruples unheard of. Yet there was valuable wool and meat to be obtained from sheep. Would not twins double the farmer's income without materially increasing his labor?

The argument that he preferred one good lamb to two poor ones did not seem conclusive to Mr. Bell, for the farmer most certainly had no objection to many pig babies, and neither the pig nor the dog mother had difficulty in rearing a large proportion of their children to fine maturity. Why could not the sheep do so too? The problem fascinated Mr. Bell. Here was what seemed to him an opportunity to satisfy his scientific curiosity, and at the same time serve the people among whom he had made his home.

Mr. Bell began the investigation of his problem by a careful physical examination of the sheep themselves, and soon discovered that while dogs have several *milk-bags,* and pigs, with much larger litters, have a great number of them; sheep as a rule only possessed one pair. Here, he considered, might lie the cause of the difference in the number of young produced. Of course the number of children a mother can profitably rear must bear some proportion to the amount of milk she had for them, and this also was dependent on the number of milk-bags, or nipples she possessed. The problem therefore at the very outset narrowed down to the possibility of multiplying the number of nipples found on a sheep.

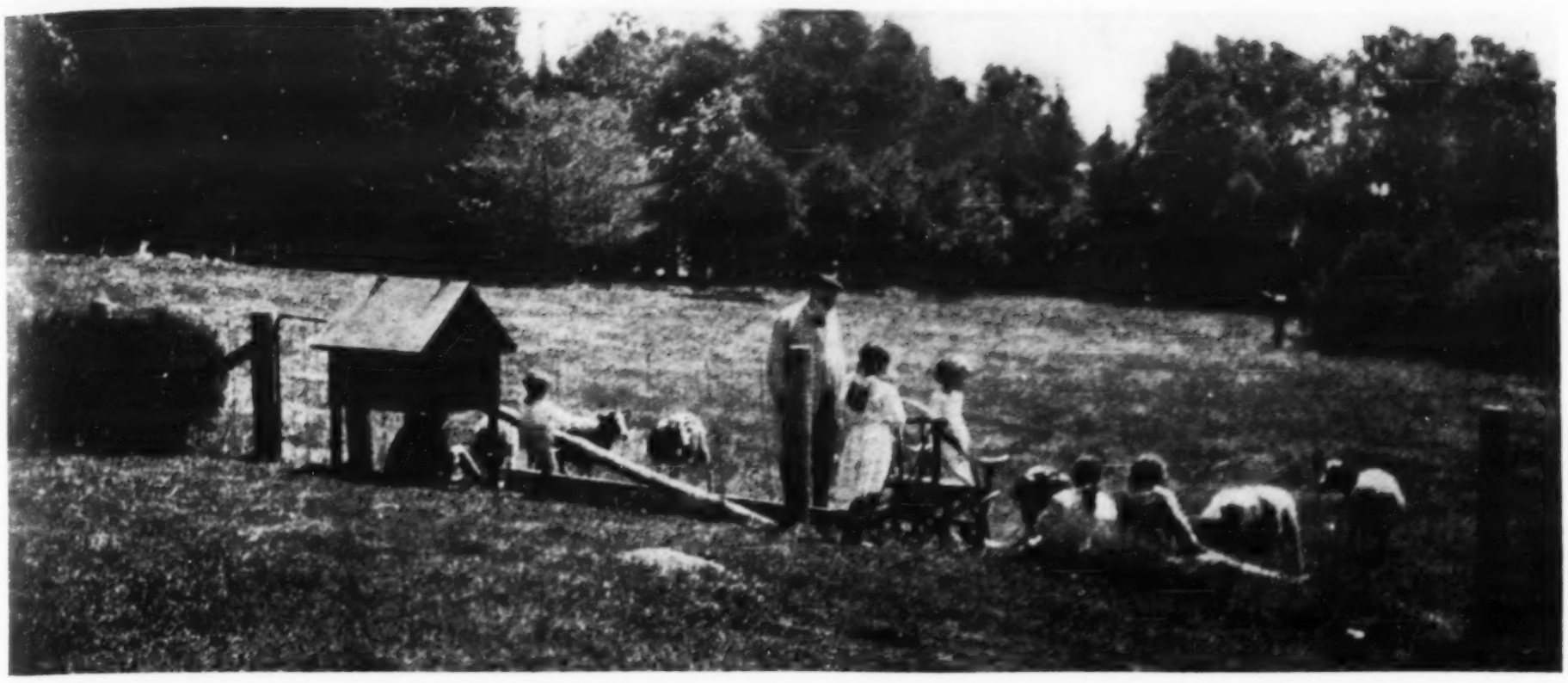
Mr. Bell noticed traces of rudimentary nipples on some of the sheep examined, and gathered confidence that by a careful scientific process of selection, these rudimentary nipples could be developed into functional milk-bags, secreting sufficient milk for the proper rearing of a number of lambs at a birth.

In such manner began the experiments to create a many-nippled breed of sheep, ultimately to be developed into a true twin-bearing variety. These were continued with varying degrees of success, but never-failing interest on Mr. Bell's part, to the end of his life. A great amount of time, study and personal labor was bestowed upon them every year. Whenever possible he was at hand to welcome the lambs in early spring, and to superintend the mating in the autumn. On one occasion he even crossed the Atlantic largely for that purpose, returning to Europe afterwards.

During the first years Mr. Bell paid especial attention to the details of the care of his sheep throughout the long Northern winters. Believing that high, dry pasturage was particularly beneficial, and that the division of animals into small groups made their protection against epidemics more easy, he built a veritable village of small sheep houses on the top of Beinn Bhreagh. He named this "Sheepville" and it had regular main and cross streets, which also had their individual names. Nearly every day for some years he conducted his sometimes rather reluctant family up the mountain, often through deep snow, to visit those sheep, and they became personally acquainted with Generals Grant and Lee, the first sires of the breed.

It was not practicable, however, to remain every winter at Beinn Bhreagh, and gradually the personal care of the sheep was left to shepherds, who unfortunately did not always deserve the confidence reposed in them. On one occasion the whole flock was almost wiped out of existence by the indifference of a shepherd, who left it outside the houses one night during a wild March blizzard; on another only three sheep escaped the ravages of wild dogs. Even when Mr. Bell went to the expense of importing a medical student from Washington to supply his own place during an enforced absence, he can hardly be said to have been more lucky, since the scientific interest of this gentleman was so keen that he cut open one of the crack ewes to see if it really had twins! It is perhaps permissible therefore to question whether, with more intelligent understanding and greater care on the part of his assistants, Mr. Bell might not have advanced further in the establishment of his variety of six-nippled, twin-bearing sheep.

However this may be, Mr. Bell himself never failed in the devotion with which he conducted his own share of the work. The scope of the investigation indeed narrowed. When Davidson left his employ some years ago he discontinued the minute weighing of each sheep before and after meals, and during rain and sunshine, and the individual feeding of measured quantities of food and observations on the influence of greater or less food, or different kinds of food on ewes during, and after, or before pregnancy, which some one protested was likely to weigh the animals out of existence! But there never was any diminution in the amount of care exercised in the selection of sheep for continued breeding. The languor of illness was already on him when he made the examination of the sheep on which this last summary was based, but there was not the smallest deviation from the usual routine. The sheep were gathered into one of the barns, the mother ewe and her lambs identified; the ewe's number looked up in the catalogue, holding it there while Mr. Bell and the farmer critically examined each nipple. Where the animal examined was a ewe the nipples were tested to ascertain whether they had functioned.



FEEDING THE SHEEP

FIGURE 1. Dr. Bell always kept a box of oats by the gate of the sheep pasture, which was very close to his house. Very often when he came back from his office in the late afternoon he would take some of his grandchildren down to feed the sheep. He was delighted in having his flock tame enough so that they would eat from his hand.

In the case of the lambs, both male and female, the size and position of the nipples with reference to each other was carefully noted and measured. Often for further elucidation profile drawings were made in the note-book. Then the size and general bodily condition of both sheep and lambs were considered, and decision rendered whether or not all requirements had been successfully met. If the verdict was unfavorable the ears of the lamb were simply clipped to prevent future confusion, and it was discarded from "Mrs. Bell's Twin-Bearing Flock." Holes were punched in the ears of the accepted sheep after a method of Mr. Bell's own devising, which through their position designated the number assigned to that particular lamb in the sheep catalogue. This number was given only to that sheep and will always identify it beyond doubt. When the owner of it, whether from failure to meet later requirements or from other causes, no longer belongs to the flock, that number still remains in the catalogue, mute evidence of such a sheep having once existed.

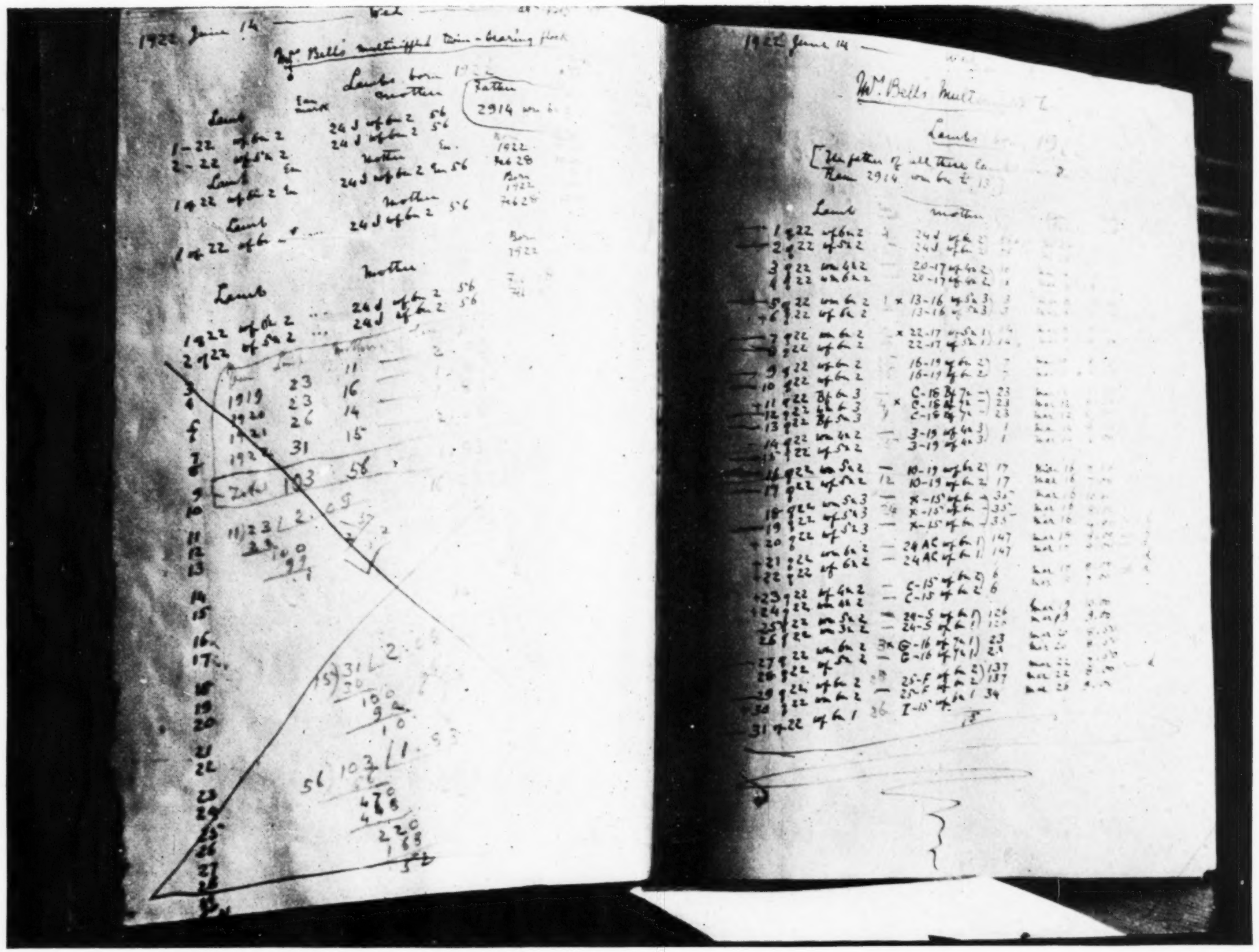
In all, Mr. Bell this year examined in this minute way fifty-one sheep. It involved two mornings of hard work on the part of all four men engaged, and Mr. Bell followed this by four nights of labor, going over the results and tabulating them. This meant filling ten large sheets of his note-book with several columns of figures and notes written in his own small handwriting. All this was gone through before the summary could be started.

Mr. Bell, of course, must have been very tired at the finish, but he was too much interested and pleased with the condition in which he found his flock, to be even aware of fatigue.

The Summary is presented exactly as Mr. Bell left it, and it is perhaps interesting to note that the language is exactly as it came from his lips, without change or correction. He looked the original dictation over, and directed that it be typewritten as it stood.

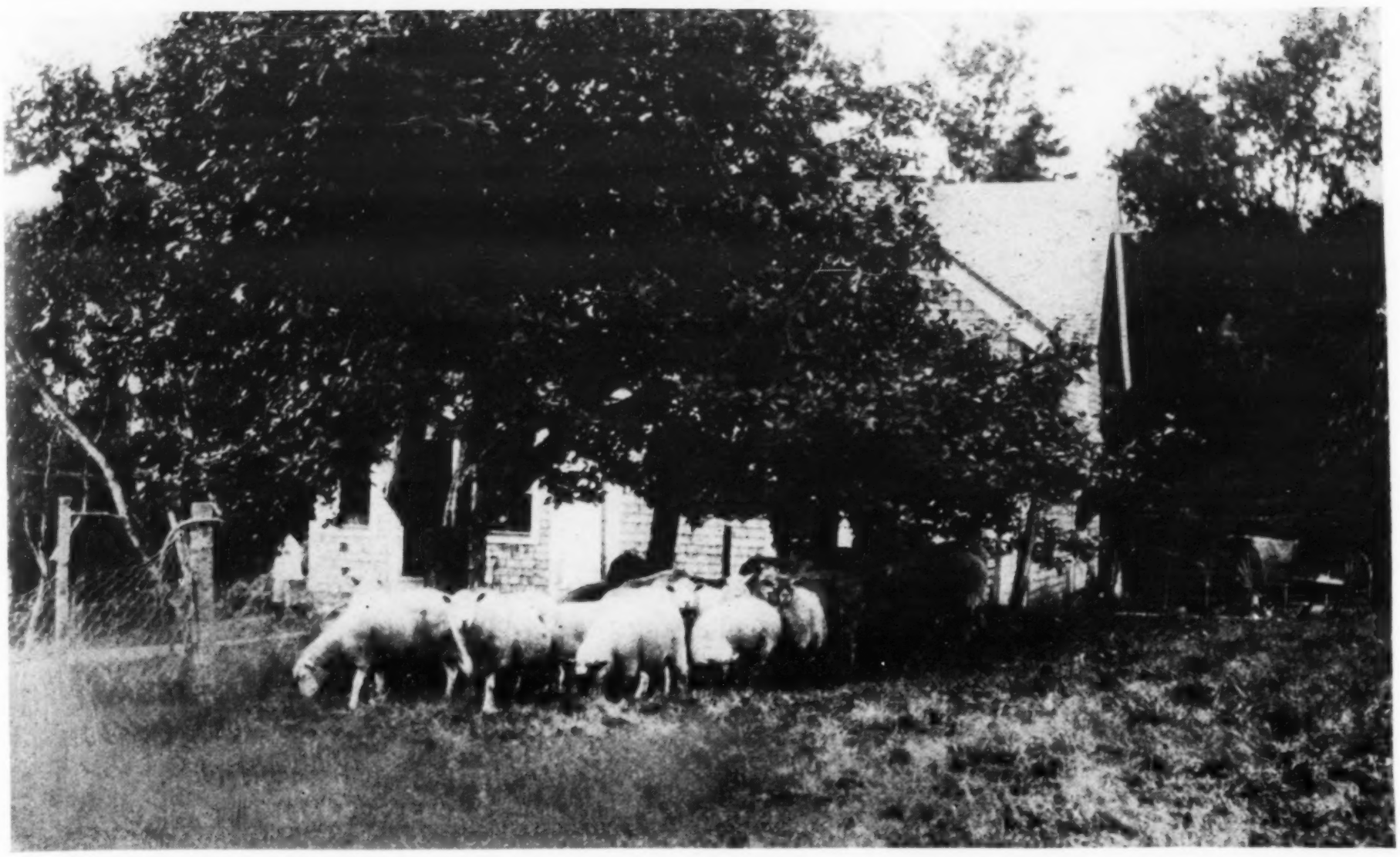
He would, of course, have made changes in its wording, had he himself prepared it for publication, for he was very critical of every word used and in the construction of every sentence. The formation of the last two sentences Nos. 3 and 4 in the paragraph describing the result of the process of selection in "Mrs. Bell's Flock," for example, will not scan, but is left untouched.

Mabel Gardiner Bell.



ALEXANDER GRAHAM BELL'S LAST CONTRIBUTION TO SCIENCE

FIGURE 2. Mr. Bell's last work shortly before his death was to note down in his book of "Home Notes" the size, number, and distribution of the nipples of the twin lambs born in the spring of 1922. This he did with that same painstaking accuracy with which through all his life he recorded his observations. The above is a photograph of a page in his notebook as his pen left it. The abbreviations, and the system of numbers, he developed to make the record work easier. Nothing was ever allowed to go unverified and it is interesting to see how he checked up the very simple problem on the left-hand page by "Casting out nines," which method he learned from the census tabulators with whom he was associated when he had charge of the



"MRS. BELL'S LITTLE FLOCK"

FIGURE 3. Mrs. Bell's little flock of multi-nippled twin-bearing sheep photographed in August, 1922. This flock was made up of selected ewes having four or more functional nipples, and whose first lambs were twins. Photograph by David Fairchild.

IN[1] 1914 I had made up my mind to give up the sheep-breeding experiments which I had been carrying on since 1890, by handing the sheep over to a younger man, Mr. J. G. Davidson, of Stewiacke, N. S. Mr. Davidson had had charge of the sheep on Beinn Bhreagh for some years previously and was thoroughly familiar with the experimental plans adopted. I made an arrangement with him to carry on the experiments in Stewiacke, N. S., for at least a period of five years as a commercial enterprise of his own.

By 1914 we had developed a six-nippled breed of sheep, but considerable difficulty had been experienced in getting the flock to breed truly to the point of selection adopted. This was shown by the fact that the best nippled sheep on the place were the offspring of sheep that had been purchased from farmers who had used our rams, and very few of them were of our own breeding on both father's and mother's side.

In 1914 the best nippled sheep were formed into a flock and removed to Stewiacke, N. S., in charge of Mr. Davidson, and we had an auction sale of all of the other sheep on the place to farmers who lived around here. After having kept careful sheep breeding records for twenty-four years, I felt rather lost at first to find myself without any sheep of my own breeding and then discovered that Mrs. Bell also felt very badly over the fact that I had deprived myself of all my sheep breeding material. In fact she felt so badly over the matter that she made private arrangements with Mr. John MacDermid to buy in a few of the sheep for herself, in the hope that I would take them up again. To my surprise therefore, I found after all that we were still in possession of a small flock of sheep, consisting chiefly of sheep that no one else wanted to buy! Among these sheep was a young ram No. 2308, a black male six-nippled twin. Its father was also a six-nippled twin, and the mother, too, so that he was presumed to have a hereditary tendency

[1] Copied without alteration from Mr. Bell's notes.

A MULTI-NIPPLED TWIN-BEARING EWE

FIGURE 4. This ewe is earmarked 13 of the Beinn Bhreagh flock. She has six functional nipples, as shown in Figure 5. The first problem in developing a twin-bearing race of sheep was to multiply the natural milk supply so that more than one lamb could be adequately nourished. Thus the difficulties of producing a twin-bearing strain are greatly increased at the start. Photograph by David Fairchild.

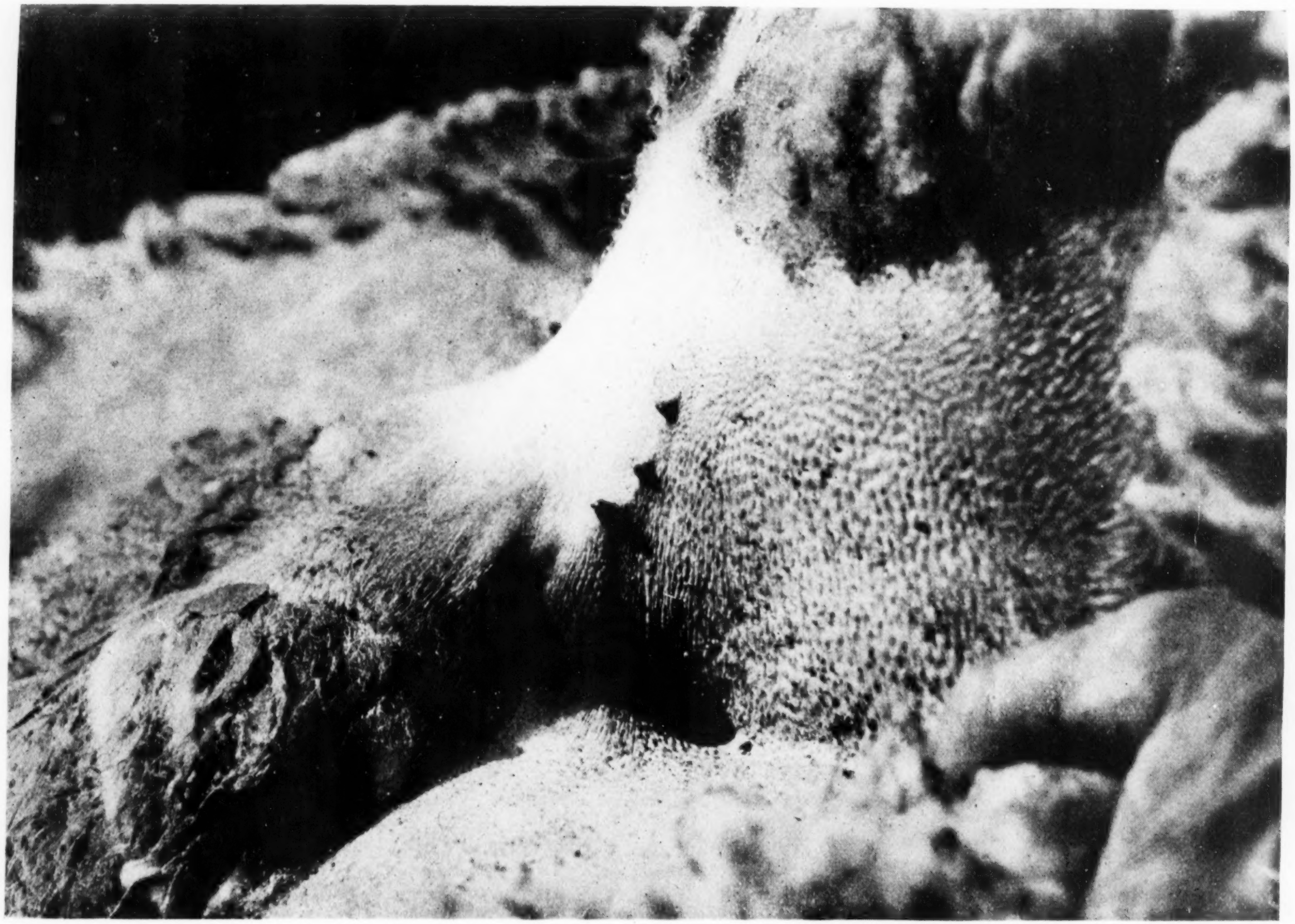
than one lamb could be adequately nourished. Thus the difficulties of producing a twin-bearing strain are greatly increased at the start. Photograph by David Fairchild.

SIX FUNCTIONAL NIPPLES

FIGURE 5. These are the nipples of the ewe shown in Figure 4. Not only does she have four extra nipples, but she bears twins as well. By selecting ewes with this desirable combination of characters, and mating them with rams from a twin-bearing multi-nippled strain, Dr. Bell hoped to develop a breed that would multiply with greater rapidity than do the recognized breeds of sheep today. Photograph by David Fairchild.

A SIRE OF THE MULTI-NIPPLED BREED

FIGURE 6. This ram, earmarked 13 of the Beinn Bhreagh flock, has six non-functional nipples, as shown in Figure 7. By mating such a ram with twin-bearing multi-nippled ewes, many more lambs would be expected to be multi-nippled than would be from a sire that had only the normal number of non-fractional nipples. Photograph by David Fairchild.



UNDEVELOPED NIPPLES ON RAM THIRTEEN

FIGURE 7. Showing the small non-functional nipples of the ram shown in Figure 6. Three nipples are clearly visible, and the tips of two of the others can just be seen. Photograph by David Fairchild.

FOUR FUNCTIONAL NIPPLES

FIGURE 8. Dr. Bell found that it was not very difficult to get ewes with supernumerary nipples, but that it was necessary that these extra nipples should be functional. This ewe was purchased from a farmer in the neighborhood of Beinn Bhreagh. It is probable that she has the blood of one of Dr. Bell's multi-nippled rams in her veins, as they were loaned to the farmers in the region. Photograph by David Fairchild.

Beinn Bhreagh. It is probable that she has the blood of one of Dr. Bell's multi-nipplied rams in her veins, as they were loaned to the farmers in the region. Photograph by David Fairchild.

UDDER OF EWE EARMARKED SEVEN

FIGURE 9. Five of the six functional nipples are shown. One pair is larger than the other four, but all of the nipples produced milk. Dogs and pigs have a larger number of nipples than this, and rear proportionally larger families. There is evidently a definite relation between the number of young born and the amount of milk available to feed them. Photograph by David Fairchild.

toward the production of six-nippled and twin offspring. However, nobody wanted a black ram, and John MacDermid bought him in for a song, for Mrs. Bell's flock.

Mrs. Bell was more interested in the production of a twin-bearing stock than in one six-nippled. This was the origin of the twin-bearing flock, and after the sale I found that instead of having no flock to look after I was called upon to care for two, a six-nippled one at Stewiacke, and a twin-bearing one at Beinn Bhreagh.

The principles of breeding were different for the two flocks. Mrs. Bell wanted twins and was satisfied that the ewes should have only four nipples, so long as the second pair of nipples were of the same size as the primary pair and were functioning—yielding milk. The principal point of selection in her flock was to keep lambs having the second pair of nipples as large as the first. They might have five or six or even more, but she considered these unimportant, provided that they had at least four well-developed, well-separated nipples yielding milk.

An examination of her flock revealed the fact that we had in the past been too anxious about the mere number of nipples instead of their size and general development. In nearly every case the supernumerary mammae were small and not functional in adult life.

This doubtless had been the reason for our failure to establish the six-nippled tendency as a hereditary trait, so that the best nippled lambs were exceptional creatures found in the flocks of farmers who had used our rams. The lambs purchased from farmers were designated by letters of the alphabet so that it was easy to distinguish the ewes that had been purchased from those of our own breeding.

In process of time we got rid of the lambs with small extra nipples, keeping only those with nipples moderately developed, and it really was curious to note how many of the sheep ultimately retained had mothers with the letters of the alphabet in their names. (Footnote by Mrs. Bell: It should be noted, however, that in nearly every case these purchased sheep have been found to be descendants of Mr. Bell's rams and it is possible to trace each one to its particular ancestor—whose number is preserved in the catalogue.)

Finding that very few of our lambs had extra nipples of the desired size, and realizing that it would take a long time to develop a small flock, we sent out an exploring expedition to examine sheep of the surrounding farmers and see whether we could not pick up a few adult ewes with extra nipples as large and well developed as the primary suckling pair. Mr. MacIver was very successful in this and succeeded in purchasing no less than sixteen ewes in which the secondary pair of nipples were of enormous size. They not only yielded milk but had evidently been sucked by their lambs. These ewes were added to the farmer's flock as we could not very well give them identifying names as their ears were already mutilated by the farmer's clippers. We have obtained from these ewes quite a number of lambs with secondary nipples apparently as large as the primary pair, and these have been added to Mrs. Bell's flock.

After the sale of sheep in 1914 I found myself special adviser in chief to two distinct flocks, 1. Davidson's six-nippled flock at Stewiacke. 2. Mrs. Bell's Twin-bearing flock at Beinn Bhreagh and to these we speedily had to add a third—the farmer's flock at Beinn Bhreagh, consisting of sheep which had been rejected from Mrs. Bell's flock and remained in Mr. MacIver's care for sale or other disposal.

The ewes of the farmer's flock that were wintered were mated with thorough-bred Shropshire Society rams with the object of improving the fleece and the hope that some of the lambs with improved fleece would turn out to have the characteristics desired for Mrs. Bell's flock, and thus enable us

to introduce the improved fleece into Mrs. Bell's Twin-bearing flock.

The principles of selection adopted in Mrs. Bell's Twin-bearing flock were as follows:

1. The nipples of the lambs were examined. The lambs having four or more well-developed, well-separated nipples of about equal size were retained in the flock and those that did not come up to this requirement were transferred to the farmer's flock.
2. In the autumn the lambs remaining in Mrs. Bell's flock were weighed, and the average weight ascertained. The lambs weighing more than the average were retained and the others transferred to the farmer's flock.
3. Innumerable experiments in the past having demonstrated that when mating was accomplished in October the proportion of twin lambs was very much greater than when mating occurred in November, and that very few twins resulted from December mating, the October mating season was retained.
4. When the lambs became two years old some of them were found to have twins of their own, while others had only single lambs. The ewes that had twins when two years old were retained in Mrs. Bell's flock and the others transferred to the farmer's flock.

As a result of these processes of selection the adult ewes of Mrs. Bell's flock consist of:

1. Sheep having four or more well-developed, well-separated nipples yielding milk.
2. Ewes weighing more than the average weight of ewes of their age.
3. They were all of them ewes that had had twins when two years of age.
4. They were all mated in October and had their lambs in March.

It was found that with very few exceptions these ewes continued to bear twins or triplets every year with hardly any single lambs. The few failures were transferred to the farmer's flock, and we now find that the adult ewes of Mrs. Bell's flock constitute a true twin-bearing stock. They always give us twins or triplets with hardly a single lamb, and the twins and triplets born are found to be in the autumn fully the equals in weight of single lambs, showing that the mother yielded milk enough for the support of more than one lamb.

We are uncertain as yet whether the twin-bearing tendency is a hereditary characteristic, for the ewes transferred to the farmer's flock were mated in December and very few of them have twins born in May. The flock, however, has been too small to enable us to carry out experiments to determine this point with certainty. All that we can say is that Mrs. Bell's flock can be relied upon to give us twins and triplets every year with only an occasional reversion to single lambs.

For example, thirty-one lambs were born this year: of these only one was a single lamb; twenty-four were twins (twelve pairs); six were triplets (two sets).

Special Notice

Since the death of Mrs. Bell, Jan. 3, 1923, her daughters have felt the desirability of placing the multi-nippled breed of sheep in the hands of breeders who would be interested in continuing Mrs. Bell's experiments or in preserving the two hereditary characters of multi-nipples and twin-bearing for future use in the improvement of established breeds, to which these characters could be be added to advantage.

I shall be glad to get into communication with institutions or with breeders of established reputation who are in a position to utilize in a thoroughly scientific way Mr. Bell's multi-nippled breed of sheep.

—[EDITOR.]

HEREDITY AND TUBERCULOSIS

A Review

A GENERATION ago, it was almost universally supposed that tuberculosis was due to heredity. Then medical opinion was led astray, and for some years the genetic factors in the case were depreciated. During the last decade a number of careful studies have corrected this mistake, until it is now clear that the inheritance of lack of resistance is one of the principal causes of death from consumption.

While in the United States last year, Albert Govaerts, director of the Office Belge d'Eugenique, made a study of this subject at the Eugenics Record Office, and his results have been published as *Bulletin No.* 23 of that office.[1] He reviews in a sketchy and inadequate way some of the other studies of the subject, notes the important work of Sewall Wright and P. R. Lewis on guinea pigs, and then publishes his own contribution, which is an analysis of family histories taken from the archives of the Eugenics Record Office.

The analogy of the breeding experiments agrees very nicely with the conclusions that had previously been drawn as to the inheritance of resistance to tuberculosis in man. Tests made on more than 100 guinea pigs belonging to five closely inbred families show marked differences in susceptibility among the different families, and the rank of the various families in respect of resistance to tuberculosis bears no relation to their rank in respect of the various factors of general vigor. It is thus clear that independent hereditary factors are involved; moreover, in particular crosses the average of the progeny is consistently superior to either parental line, indicating that the latter are susceptible for different reasons, each being able to supply what the other lacks. In general, resistance is dominant over susceptibility, and there is equal transmission by sire and dam, and to sons and daughters.

When the various races of mankind are considered, a similar state of affairs is found. Negroes are notoriously susceptible to consumption; so are the American Indians, and in general, all the aboriginal peoples of the western hemisphere, who have been exposed to the disease only since 1492, and therefore have had not an opportunity to develop, through natural selection, a degree of immunity or resistance which is found among some of the peoples of the Old Word, where the bacillus has been at work for thousands of years, in all probability. And among the races of the Old World, the differences are striking enough: Louis Dublin has pointed out that in the state of New York the death rate from tuberculosis among the Irish is some four times as high as that of the Russians or Italians, males being considered in each case.

The problem was long ago attacked statistically by Karl Pearson and associates, who showed in a number of fundamental papers that there is about as much resemblance between parent and offspring, in prevalence of tuberculosis, as there is in respect of any of the commonly accepted inherited traits such as eye color or stature. On the other hand, the resemblance between husband and wife, in regard to tuberculosis, was not great, despite their prolonged and intimate association. All the evidence indicated that heredity, rather than mere contact with an infected person, is the most important factor in determining the incidence of

[1] Carnegie Institute of Washington, Eugenics Record Office, *Bulletin No.* 23. The Hereditary Factor in the Etiology of Tuberculosis, by Albert Govaerts, M. D. Reprinted from the American Review of Tuberculosis, September, 1922, vol. vi, pp. 547-565.

the disease. Raymond Pearl adds that "a tuberculous person, chosen at random in the working population of Baltimore, will have nearly six times as many blood relatives tuberculous as will a non-tuberculous person."

Supplementing these lines of investigation, whose extent and usefulness has here hardly been hinted at, Dr. Govaerts has made a more detailed analysis of 214 families, representing 5,629 individuals, in which occurred 185 tuberculous matings and 29 non-tuberculous matings. He calls "a tuberculous mating one in which the father or mother, one or both, are tuberculous or whose fraternity and ancestry are tuberculous. Non-tuberculous matings are matings in which no member of the family is tuberculous or belongs to a tuberculous stock."

The individuals are classified in two groups, "namely, close contact and non-close contact with tuberculosis of the lungs. Close contact means a close contact with a case of tuberculosis of the lungs during the whole or a part of life; non-close contact implies the opposite." If infection is more important than blood relationship, then most of the tuberculous individuals ought to be discovered to have had close contact, more or less prolonged, with some diseased person.

The opposite is the fact. The larger number of the tuberculous persons have not been in close contact with a "case."

On the other hand, when the material is classified according to the amount of tuberculosis in the ancestry, the frequency of the disease among the children is found to vary directly with its frequency among their forebears.

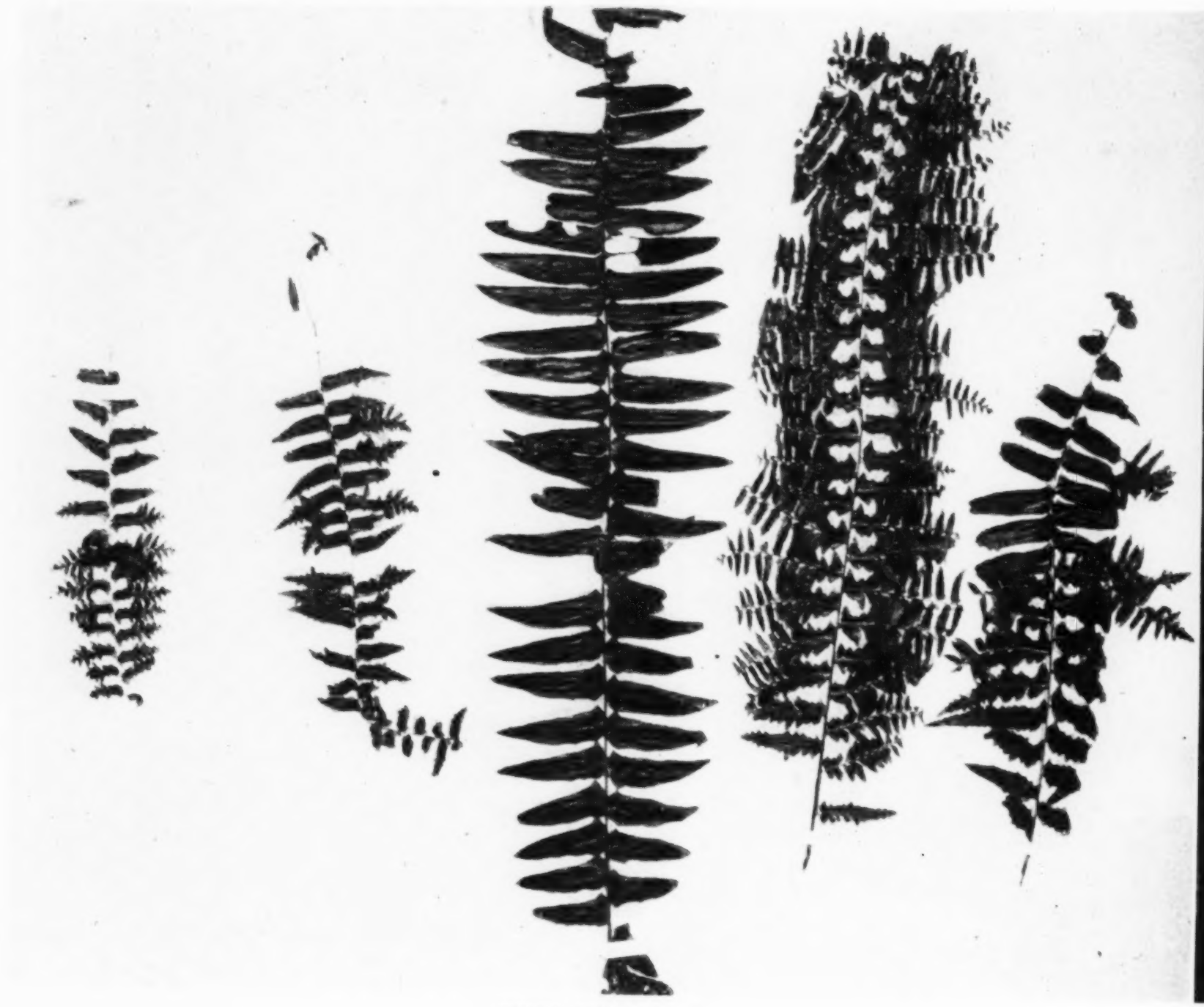
The unexpected result is developed that the influence of the father, in transmitting weakened resistance to the disease, is greater than that of the mother. "Wherever the paternal stock alone is known to be tainted, more of the children show active tuberculosis than when the maternal alone is known to be tainted." As the children are much more closely associated in daily life with the mother than with the father, and most of them have been nourished by her milk in the first year of life, this fact—if substantiated—tends still further to show the relatively small importance of the mere matter of contact or exposure.

Dr. Govaerts discusses somewhat vaguely the question whether the results of his studies indicate a simple Mendelian form of inheritance. He reaches no conclusion, and his material hardly lends itself to analysis on this point.

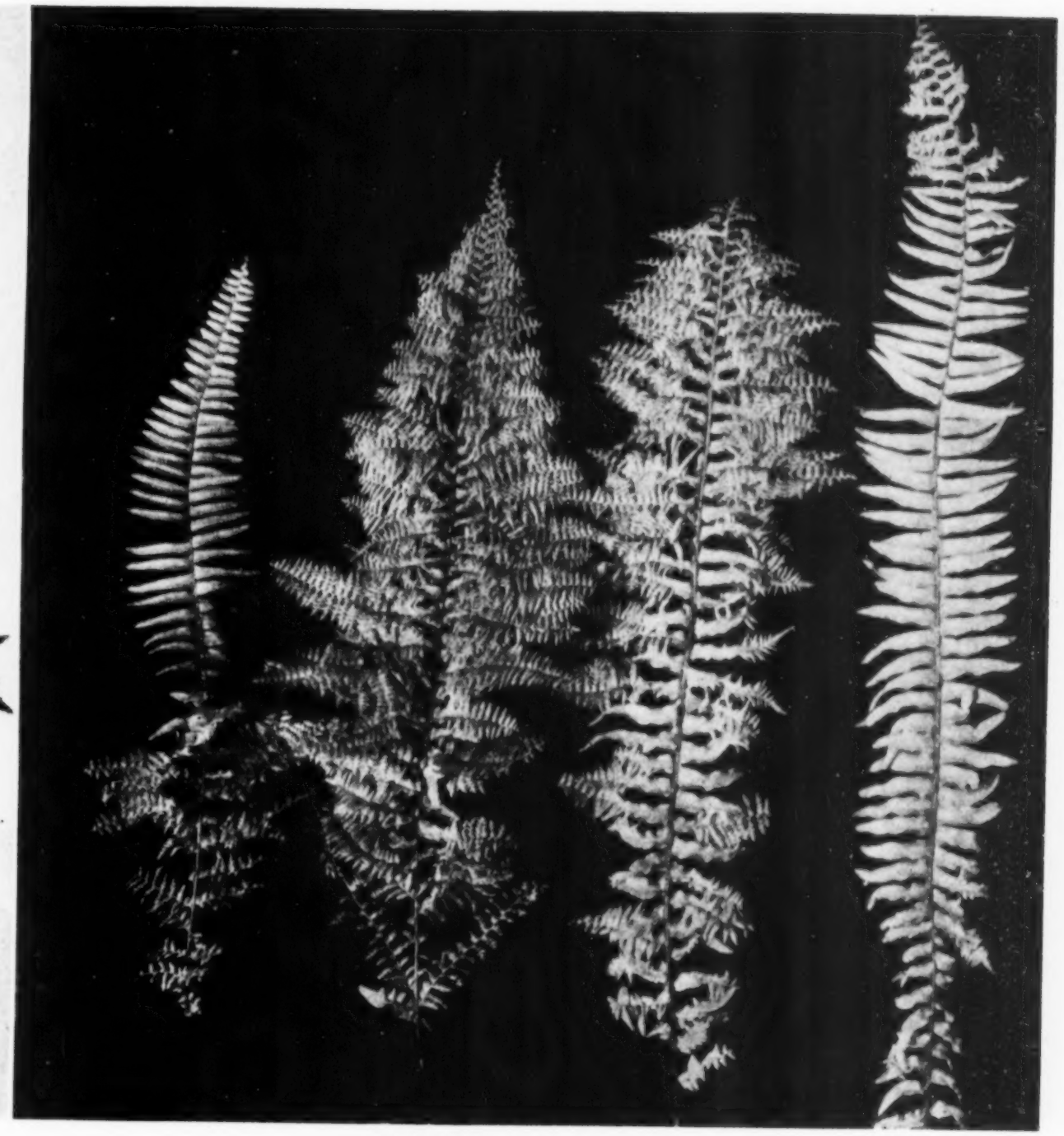
Outlining his own interpretation of the results of his study, Dr. Govaerts says:

> One cannot maintain that there can be tuberculosis without infection, but various considerations may still be urged to support the view that different persons have the power to resist the infection in different degrees, and that in consumptive families a lack of resisting power is transmitted from gametes to children. The tubercle bacillus is everywhere about us. Some people entirely escape its attack, while in others the disease may occur in such a slight form that the person attacked recovers from it without being aware that anything has been wrong.
>
> Tuberculosis is not an inheritable character in the sense in which eye color is inheritable. It belongs to a second kind of heredity called *indirect heredity*. Infection and immunity are causes, but they do not exclude inheritance. Biologically speaking, people inherit directly a constitutional make-up, possibly functional, chemical, and structural, with a certain amount of power to resist tuberculosis or other related diseases.
>
> From the social and eugenical point of view it is very important that tuberculosis is transmitted approximately in a Mendelian sense. So it seems possible to establish some principles based on the law of averages.
>
> From present knowledge no one is able to give advice to normal persons or one apparently normal for a contemplated marriage. Advice is possible only in extreme cases and we need still more minute investigations and studies. Nevertheless, it will be useful to dissuade marriage between two stocks in which the same defect is apparent. In such stocks consanguineous marriages are dangerous. A tuberculous subject will find more advantage for his progeny by marrying a person belonging to a resistant strain. Eugenical marriages should be between normals and those free from defects.

PAUL POPENOE.



Wild Whitmani



Cultivated Whitmani

WILD AND CULTIVATED STRAINS OF THE "WHITMANI" FERN

FIGURE 10. At the left are the leaves sent in by Mr. Simpson from plants which have grown wild for twelve years at Little River, Florida. They correspond in general character of division to leaves produced by a reverting strain of that variety grown under greenhouse conditions, except that they are smaller than normal. The once-pinnate leaf at the left is probably a temporary vegetative reversion of the divided type. At the right are the leaves of a reverting strain of *Whitmani* grown at the Brooklyn Botanic Garden. These leaves average larger than those sent by Mr. Simpson, and the amount of division is greater, nearly thrice-pinnate, but this would be expected under the better conditions of greenhouse culture. It is an interesting point that this particular strain, which has been under culture at Brooklyn for eight years still maintains the characteristics represented in the picture taken in 1916. From it may be raised runner progeny of practically typical *Whitmani* characteristics, but it has not been possible to separate a strain in which the once-pinnate condition is entirely fixed.

ARTIFICIAL VARIETIES UNDER NATURAL CONDITIONS

Can the Bud Sports of the Boston Fern Thrive Under Conditions of Natural Selection?

R. C. Benedict

Brooklyn Botanic Garden.

IN AN article published as a leaflet of the Brooklyn Botanic Garden (Series X No. 3, 1922), the suggestion was made that it would be a matter of considerable interest to determine experimentally whether any of the horticultural forms of the Boston fern, produced by the artificial selection of florists, would be able to stand the test of natural conditions; in other words, whether they are fit to survive on the basis of natural selection. It was further suggested that such a test might easily be made by setting out, say in Florida, under favorable wild conditions, a selection of the stronger cultivated types. Following the distribution of the leaflet a letter was received from Mr. Charles T. Simpson of Little River, Florida, which bears directly on the problem:

> Your letter of July 1 and the accompanying fern papers reached me in due time but I am a very busy old man and my eyes trouble me so I can read but little. Today I have just glanced over the papers which are very interesting.
>
> I have lived on this place, which has a couple of acres of hammock, for twenty years. When I came here *Nephrolepis exaltata* grew sparingly in a part of my hammock and on the two cabbage palmettos.
>
> Perhaps twelve years ago, I cannot remember, I turned out of my slat house a plant of the form you call *Whitmani* into a part of the hammock which had no *exaltata*, but not more than six or seven rods from a patch of it. I think I put out only a single plant,—certainly very few—but now the *Whitmani* covers irregularly over two square rods of the floor of the forest. It is a rather open hammock and not so favorable for ferns as if it were thick and damp.
>
> At least seventy-five per cent of these ferns hold to the *Whitmani* type fairly well. Now and then there is a pure (?) *exaltata* and there are some intermediates. I am enclosing a few specimens. It is possible that spores from the *exaltata* may have been borne by wind or other means and lodged among the *Whitmani;* that they may have grown and made some of the plain plants.
>
> A few of the *Whitmani* plants are growing naturally a short distance above ground on trunks of trees, not more than a foot or so.

The accompanying illustration shows the leaves sent in by Mr. Simpson. As will be seen, they manifest variable and irregular division from plain once-pinnate to twice-pinnate. Typical *Whitmani* develops thick, plumy, thrice-pinnate leaves under the best greenhouse conditions, but when grown in untoward circumstances, and especially in reverting strains, it will produce leaves of the type shown. It is not to be expected that the dense leaves of the favorable florists' environment, —rich soil, absence of competition, moist air,—would be reproduced under open conditions of a drafty hammock.

It does not follow that the plants showing only once-pinnate leaves are necessarily, as suggested by Mr. Simpson, true wild *exaltata*. The leaves sent in appeared much too thin for the wild type. In a reverting strain, *Whitmani* will normally produce occasional crowns with practically complete reversion. I could duplicate the series of leaves shown by a selection of leaves from one pot of reverting *Whitmani* in the Brooklyn Botanic Garden cultures. The plain once-divided leaves of such a plant of reverting *Whitmani*

are always thinner than leaves of wild *exaltata* grown under identical conditions and differ further in that they produce no fertile sporangia.

Two points are of special interest in connection with these plants reported by Mr. Simpson:

First, that a rather delicate, greenhouse variety of Boston fern, *Whitmani*, has maintained itself and increased over a period of twelve years under conditions of natural competition.

Second, that the plants have retained an approximation of the typical form of the leaf. Given best greenhouse conditions, it is almost certain that these naturalized plants would show the typical plume type of the normal *Whitmani*.

If any reader is in a position to make a more extended test of other varieties, I shall be glad to send a selection, including some new, unnamed types, which would answer all the requirements of specific distinction, according to descriptive taxonomy.

FURTHER POINTS ON THE RELATION OF CYTOLOGY AND GENETICS*

P. W. Whiting

Iowa Child Welfare Research Station.

IN VIEW of the recent announcement of G. H. Shull[6]† that he has actually found crossing over in Oenothera, the remarks of R. Ruggles Gates[2] in reference to the cytological conditions should be considered. Gates (p. 76) states, "As is well known, in Oenothera the chromosomes form a chain end-to-end like a string of sausages, and when they ultimately come to be side-by-side in diakinesis they are already in the short and stout condition in which twisting about each other is impossible. This is a very disturbing fact for those who write about 'crossing over' in Oenothera." Just why geneticists should be disturbed by an end-to-end arrangement of sausage-like chromosomes I am unable to understand. It is obviously up to those who insist on some other explanation of crossing over than that usually held, to show that these sausage-shaped chromosomes are of the same constitution as those that entered into synapsis. The fact that the diploid number should occur in late prophase preceding the first maturation or heterotypic division throws no light upon the stages when crossing over occurs.

Crossing Over in Fine Thread Stage

Plough[4] (p. 187) from temperature experiments with Drosophila, has shown that crossing over occurs at a very early stage when the chromatin threads are extremely tenuous, "in what resembled a late leptotene or early diplotene condition in other forms." Such stages have not as yet been adequately studied in Oenothera. Refering to this genus in an earlier paper[3] (p. 11) Gates writes, "in the earlier stages . . . .parallel threads could not be observed, and it has not been determined whether they were really absent or whether the failure to observe them was due to their extreme delicacy." Wenrich's[8] careful studies on leptotene and zygotene stages in spermatocytes of the grasshopper, Phrynotettix, which is evidently very favorable material, have

* A reply to "Some Points on the Relation of Cytology and Genetics," by R. R. Gates, in *The Journal of Heredity* for February, 1922.

† For Numbered References, see *Literature Cited*, at end of article.

clearly shown parasynapsis of very fine threads, but in view of the difficulty of fixation in much botanical material it is not surprising that this phenonemon has not been more widely observed.

Structure of First Maturation Chromosomes

The number of elements, chromatids, present in the chromosomes of the heterotypic division seems to be a bone of contention among cytologists. Zoologists have for the most part, at least recently, held that there are four, and have hence designated these chromosomes as tetrads. Botanists, as in the case of Gates, perhaps because their material is not so easily fixed, have usually been unable to see more than two elements at this stage, and have consequently preferred the term, bivalent chromosomes. Recently, however, Taylor[7] in a preliminary report on the organization of heterotypic chromosomes of the Liliaceous genus Gasteria, states that clefts appear in the ends of the metaphase chromosomes, separating monads, and that the latter are completely separated at anaphase. The conclusion is therefore unavoidable that in this plant material at least the first maturation chromosomes are tetrads in structure. The term bivalent may well be retained, nevertheless, to denote origin.

Failure to reveal the tetrad nature in many cases is evidence merely that the chromatids tend to associate much more closely in pairs than the pairs associate with each other. To use a chemical analogy, we might say that the valence of each chromatid is more or less satisfied by very close union with one other chromatid. Homologous or sister pairs may then be more loosely associated giving the appearance of double elements which are really quadruple.

Structure of Spirene Chromosomes

A comparable situation is to be observed in spireme stages, preceding maturation. It is often stated that the homologous chromosomes twist about each other in long threads. This is only partly true as I have pointed out in the spermatogenesis of Culex.[9] Two twisted chromatin threads indeed appear, but each of these threads consists in any loop of two tightly fused elements, chromatids. While the threads in one loop may represent portions of homologous chromosomes, the threads of the next loop may represent fused daughters of homologues. In other words the chromatids have changed partners at the apparent point of junction. The spireme chromosome then is really a tetrad, for it is made up of four elements.

Spireme Structure and Crossing Over

The fundamental quadruple nature of the early spireme thread is of importance in relation to genetics. Bridges[1] (p. 134) from a study of equational non-disjunction has shown that non-disjunction of the equational and of the ordinary reductional type may occur at the same time in the same "pair" of chromosomes. This necessitates crossing over in the four-strand stage. "It is impossible that a non-cross over and a cross over chromosome come from a cell in which only two strands are present. Therefore the proof that these exceptions arise from XX (or XXY) oocytes would at the same time prove that crossing over took place in this manner at a four strand stage." But since Plough's results show crossing over to occur very early, we will perhaps have to conclude that even the zygotene threads, although apparently double, are really quadruple, the double appearance being due to the same principle of "satisfied valence" which causes the later spireme also to appear double and the diakinesis tetrads in some cases to appear as "dyads."

Robertson[5] has reported precocious splitting of anaphase chromosomes in the last spermatogonial division, a cytological fact which may be taken as evidence of double nature of lep-

totene threads and hence of quadruple nature of zygotene threads.

If "change of partners" occurs between the four zygotene elements in various parts of their length, the extreme tenuity of the threads may here permit permanent breaks and refusions at the points of exchange, giving a basis for crossing over which is lacking in later stages, although "change of partners" takes place there also. Relative differences in condensation of threads at time of synapsis may therefore explain occurrence of crossing over in one sex and its failure in another.

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[3] Gates, R. Ruggles. A Study of Reduction in *Oenothera rubrinervis*. *Bot. Gazette*, xlvi:1. 1908.

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Discovery Made Simultaneously By Independent Investigators

In the two following articles on defective endosperm in maize it seems probable that the authors have independently discovered the same character, seeds that germinate on the cob. Further experiments would be necessary to prove definitely the similarity of the two defects. It is interesting if they have found the same character in two distinct varieties of sweet corn, and it is even more remarkable that the mailing of the manuscripts describing this discovery was so timed that they both reached us on the same day.

Not being gifted with Soloman's wisdom, we have avoided the rather complicated questions of priority involved by awarding the baby simultaneously to both mothers, as it were, and have printed the two articles in the same issue. Since Dr. Manglesdorf's manuscript arrived a few hours before Dr. Lindstrom's, we are giving the former priority of place.—*Editor.*

THE INHERITANCE OF DEFECTIVE SEEDS IN MAIZE[1]

P. C. MANGELSDORF

Connecticut Agricultural Experiment Station, New Haven.

DEFECTIVE seeds are heritable variations in maize in which the endosperm is lacking or is incomplete or abnormal in its development. These characters were first reported in the *Journal of Heredity* by Jones,[2] who observed them in several varieties of corn that had been self-fertilized for the first time. Crosses made by him, and later generations classified by the writer have shown that there is more than one type of this abnormality, and the first four defectives studied have been found to be genetically distinct.

In the past few years many experiment stations have begun projects for the improvement of corn by selection in self-fertilized lines. Altogether, more than six thousand strains of corn have been inbred for this purpose. This inbreeding has brought to light many recessive variations, previously covered up by the remarkable heterozygosity which exists in the average variety, and among these recessive variations there have been a large number of defective seed types. Defective seeds have appeared in all the so-called sub-species of maize with the possible exception of *tunicata* and in more than thirty representative American varieties as well as in several varieties from Spain and one from Peru. During the summer of 1922 crosses were made between many of these defectives and the four types originally tested at the Connecticut station in order to determine, if possible, the number of distinct genetic factors involved. Between fifty and sixty crosses have been made and in only one of these have the results been such as to indicate that the two defectives which entered the cross were genetically alike. It appears, then, that there are many different factors involved which cause defective seeds in maize. A brief description of several characteristic types follows:

Classification of Defectives

The defectives show varying degrees of development. There are types ranging from those which consist of only a transparent, empty, pericarp with scarcely a trace of endosperm tissue, to others in which the development is but slightly less than normal. There are others, even more extreme, in which the seed develops almost normally but fails to go into the resting stage and germinates on the ear. Between these two extremes are all gradations, and within each type is a certain amount of variation, so that it is often impossible to separate two such types when they occur on the same ear.

The defectives may be roughly classified into three groups as follows:

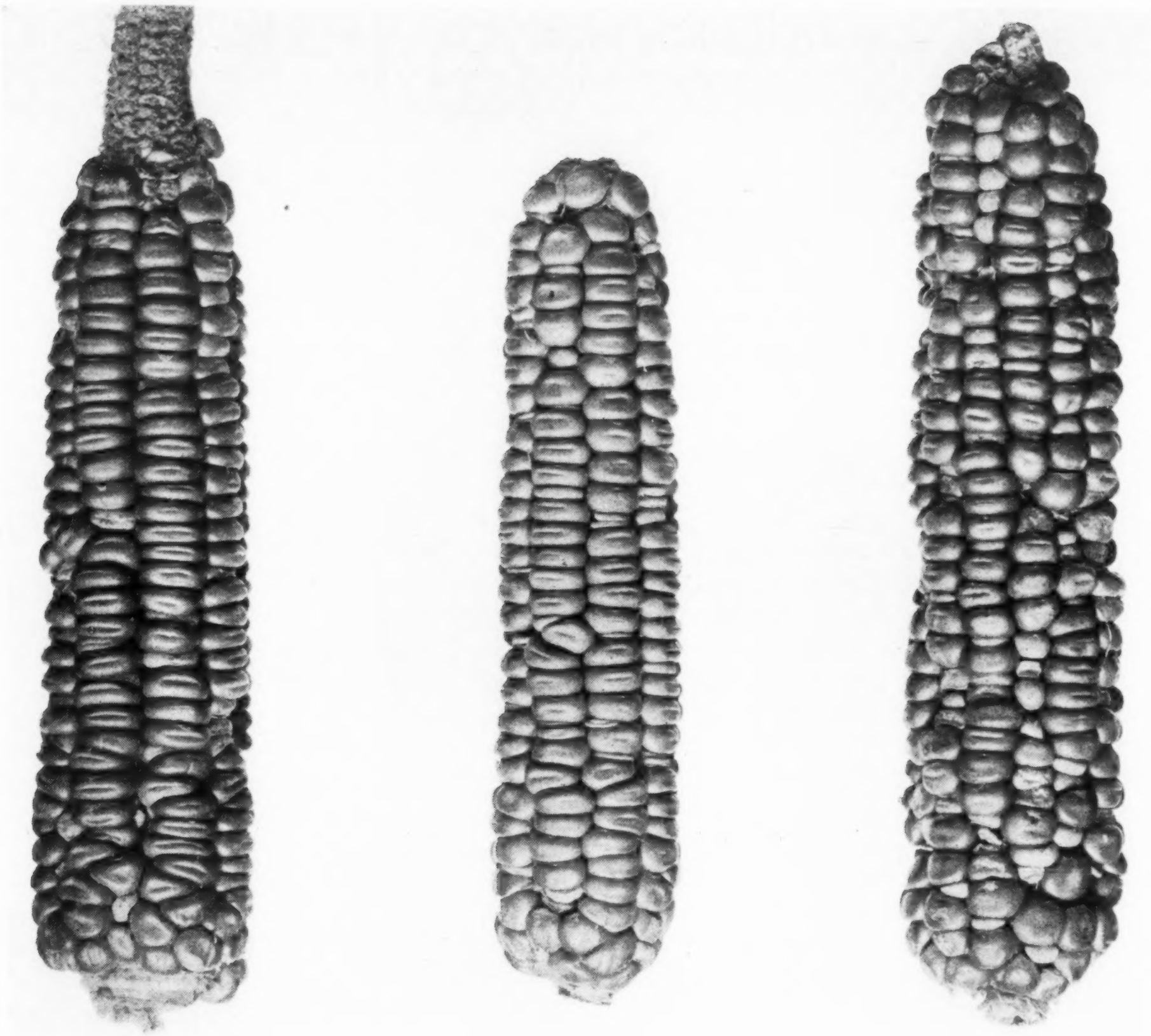
1. Complete defectives; those in which the development of the ovule is arrested shortly after fertilization.

2. Partial defectives; those in which development proceeds until a certain amount of endosperm tissue has been laid down.

3. Germinating seeds; those in which the mature seed fails to go into the resting stage.

[1] Contribution from the Bussey Institution, Harvard University.

[2] JONES, D. F. Heritable Characters of Maize; Defective Seeds. *Journal of Heredity*, vol. xi, No. 4. 1920.



Partial Defective **Complete Defective** **Both Types**

A CROSS BETWEEN TWO TYPES OF DEFECTIVE ENDOSPERM

FIGURE 11. These ears are borne on plants of the first hybrid generation, but because of the phenomenon of double fertilization in maize the endosperm of these grains is of second generation tissue. Only one type of defective grains occurs on some ears, while on others both types are found. On the ears on which both types occur they are in a 9:7 ratio, proving that the two defects are genetically distinct.

Description of Characteristic Types

A typical representative of the first group is one which Jones first observed in a commonly grown New England variety, Century Dent. This particular defective is little more than an empty pericarp, although under certain favorable conditions, it does form a trace of endosperm tissue. The seeds have a very small embryo, scarcely visible except under the microscope, but apparently quite normal in structure. When kept in a germinator at optimum conditions of temperature and moisture, these aborted seeds show a germination of about twelve per cent. The seedlings are extremely weak, as shown in the illustration, and in many cases are unable even to burst through the pericarp. Because of the almost complete absence of an available food supply, these seedlings survive but a few days. It has been possible to prolong their period of development by growing them in a nutrient agar, and it might be possible by grafting

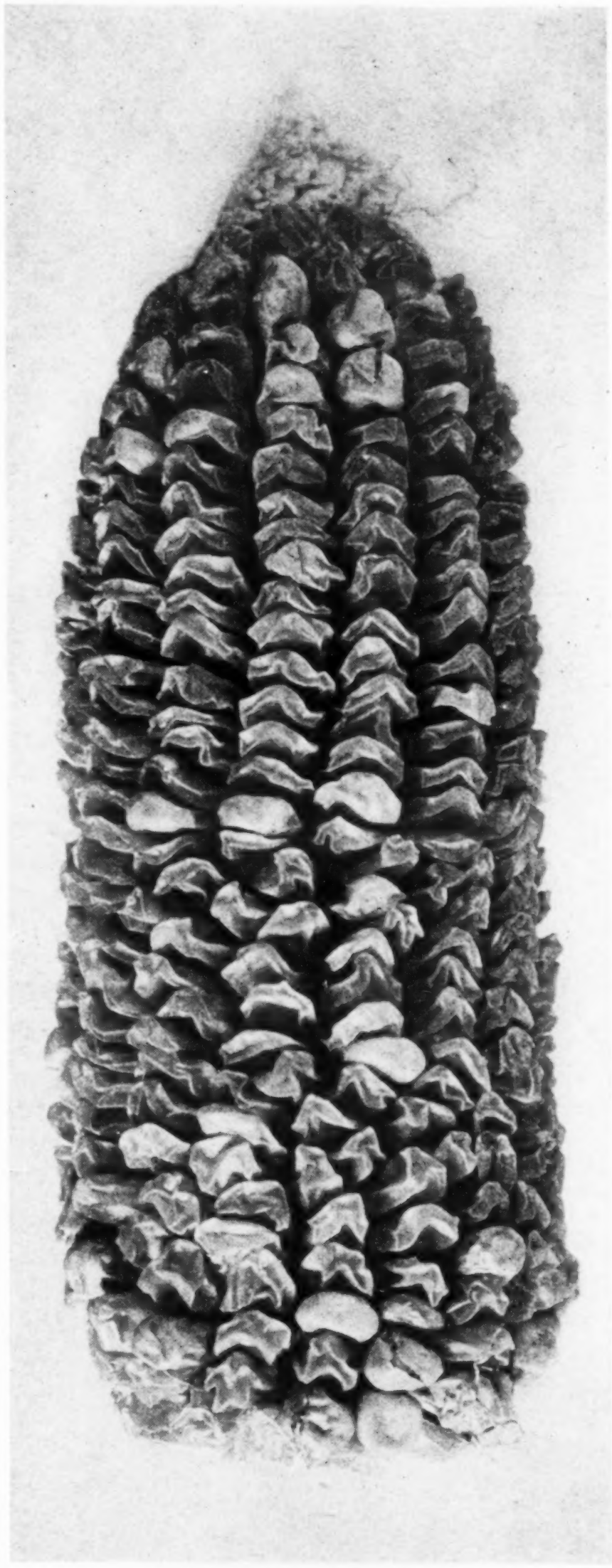
"PURE" DEFECTIVES

FIGURE 12. The lethal action of many of these defects of the endosperm is such that it is impossible to germinate seed, much less to raise homozygous, or genetically pure defectives. However, partial defectives contain enough endosperm so that it is possible to raise plants from such seed. On such plants all of the seeds are defective when the ear is self-pollinated or when cross pollinated with pollen from other defective plants. On the left is an ear segregating for partially defective grains; in the center is a self-pollinated homozygous ear of the "partial defective," and on the right is a cross pollinated ear from such a homozygous plant.

on to a normal endosperm, to bring them to maturity. Such an experiment would show whether the lethal action of the defectives is merely one of an insufficient food supply or whether other factors are involved.

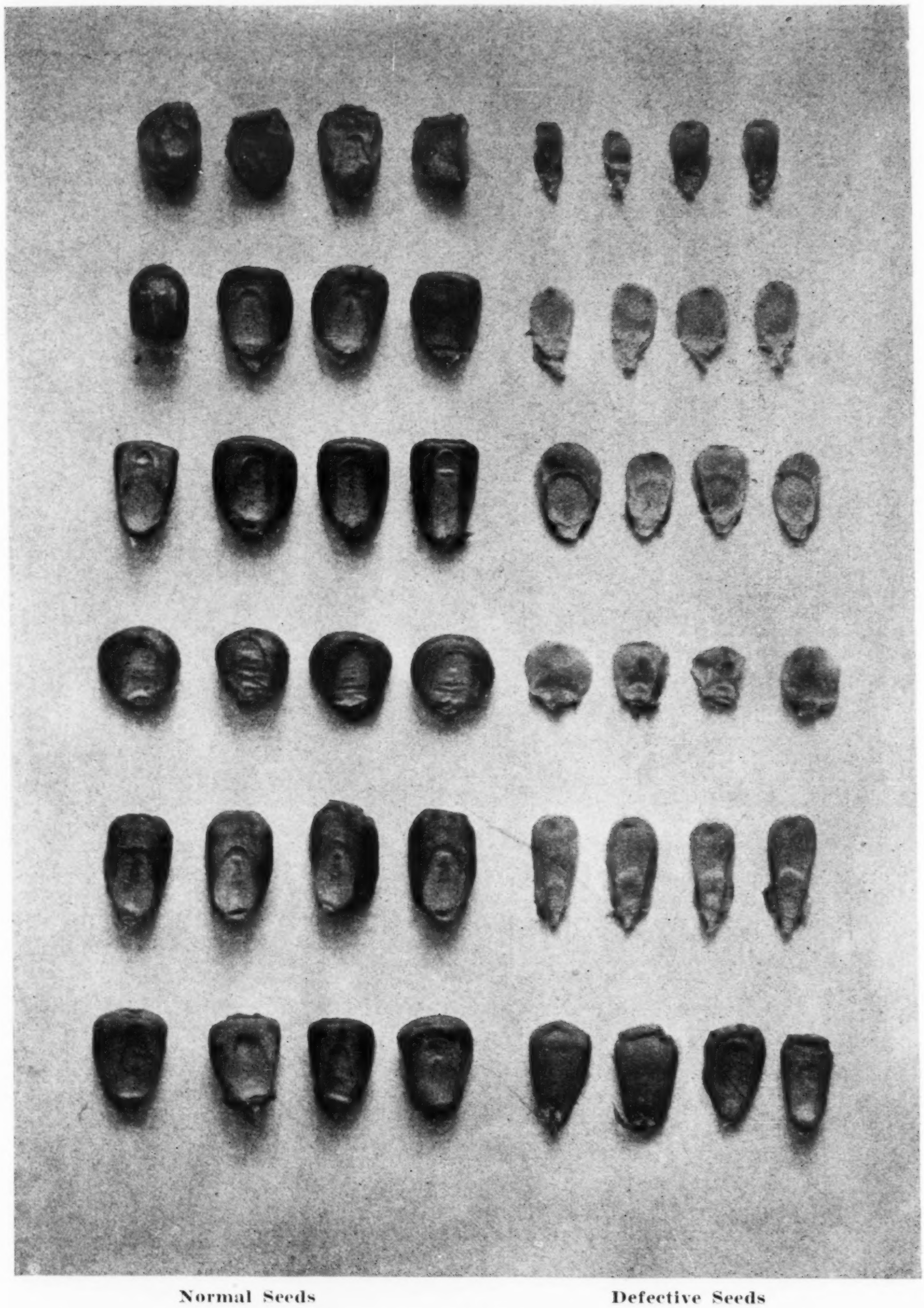
For the second group, a defective which also appeared in the variety Century Dent, is typical. In this type the development of the recessive seeds is halted only after a considerable proportion of the endosperm tissue has been laid down. It is impossible to determine whether a plant is segregating for this defective until the seeds have reached the soft dough stage, while in the case of the type described above the aberrant seeds can usually be identified soon after pollination. The seeds of the partial defective are almost normal in size but lack the lustre of fully developed kernels. The pericarp attains almost complete development and since the endosperm fills it only partially, the defectives have a shrivelled appearance. They are readily distinguished from normal seeds on the same ear and separation of the two types can be very accurately made. The development of the embryo in these abortive seeds is apparently normal in every respect and they show a germination of eighty to ninety per cent under optimum conditions. The seedlings, however, are very weak and under field conditions seldom emerge. Even in the greenhouse most of them die in several weeks. When the most vigorous seedlings are "nursed" along in the greenhouse and later transplanted to the field, it is possible to mature a few plants. An ear from such a homozygous plant is shown in the illustrations. Apparently the lethal action of this defective is purely one of an insufficient food supply.

This partial defective has been crossed with the complete defective which appeared in the same variety and which has already been described. The first generation of such a cross was normal. In the second generation several of the ears were segre-



GERMINATING SEEDS

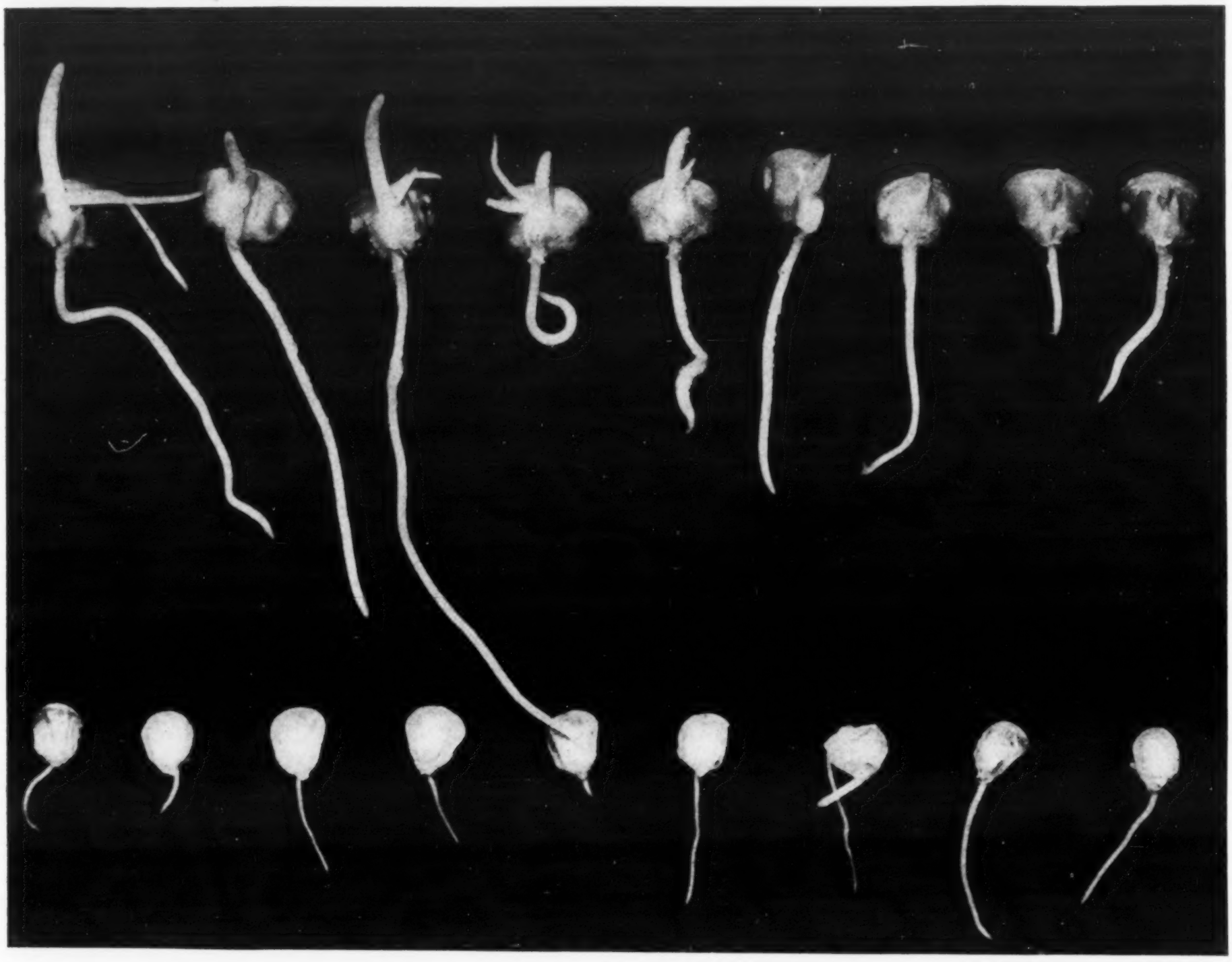
FIGURE 13. This newly discovered type of defective kernels is characterized by the failure of the embryo to go into a resting stage. The growing embryo stretches the pericarp and in extreme cases ruptures it. These grains have a characteristic swollen appearance, and are lighter in color than the other grains on the same ear. When the ear is harvested the embryo in these seeds dies from lack of water.



Normal Seeds Defective Seeds

SIX TYPES OF DEFECTIVE SEEDS

FIGURE 14. All seeds in each horizontal row are from the same plant. There are many types of defective endosperm in maize, ranging from those which exhibit only a transparent empty pericarp, to those in which development is slightly less than normal. These varying degrees of defectiveness are not the diverse expression of the same hereditary character, but each is inherited as an independent unit. Several of these defects can be brought together on the same ear, when their distinctive characteristics are all retained.



GERMINATION OF NORMAL AND DEFECTIVE SEEDS

FIGURE 15. When kept in an incubator complete defectives show a germination of only about twelve per cent. The illustration shows some of the defectives which have germinated compared with normal grains from the same ear. Unless transferred to nutrient agar the defectives proceed no farther than the stage shown in the photograph.

gating for two types of defectives in approximately a nine-seven ratio, showing that the two types are genetically distinct and not merely the same character associated with different combinations of modifying factors. The two types have also each been crossed with some fifteen other defectives from various sources and appear to be distinct from all of them, although so closely resembling several of them as to be indistinguishable.

The third group of defectives we have called *germinating seeds*. The factor for germinating seeds prevents the mature ovule from going into the resting stage and approximately one-fourth of the seeds on a segregating ear begin to germinate while still attached to the rachis. Usually the embryo grows only enough to stretch the pericarp and give the seed a swollen appearance, but in extreme cases the pericarp is burst and a well-defined root and shoot are formed. The character was first observed by Jones on a self-pollinated ear of a small New England variety, Canada Flint. It is not at all unusual, especially in New England, to find ears in the field on which part of the seeds have germinated. Ordinarily when this occurs the germinating seeds are confined to a local region of the ear which has not dried out thoroughly. On this particular specimen, however, the germinating seeds were scattered at random throughout the ear and oc-

curred in the approximate proportion of three non-germinating to one germinating. The normal seeds from this segregating ear were planted in 1922 and the abnormality again appeared, indicating that it is inherited and not merely the result of environmental conditions. On the other hand, the character is probably one, which, though genetically present, would manifest itself only under certain environmental conditions. In a dry season it might never appear, although the factors for germinating seeds were constantly present.

Germinating seeds have been observed in only two varieties at the Connecticut station and it has not yet been determined whether the two are alike or distinct.

In the variety Canada Flint, there is some relation between germinating seeds and the production of yellow color in the endosperm. The ear on which the germinating seeds were first observed was homozygous for yellow endosperm. The following season all of the germinating seeds were white. The relation is probably a physiological one which has been accentuated by the inbreeding. If it is true genetic linkage, then a mutation for white seeds must have occurred and this mutation is completely linked with the factor for germinating seeds. Another season's result should show definitely whether such is actually the case.

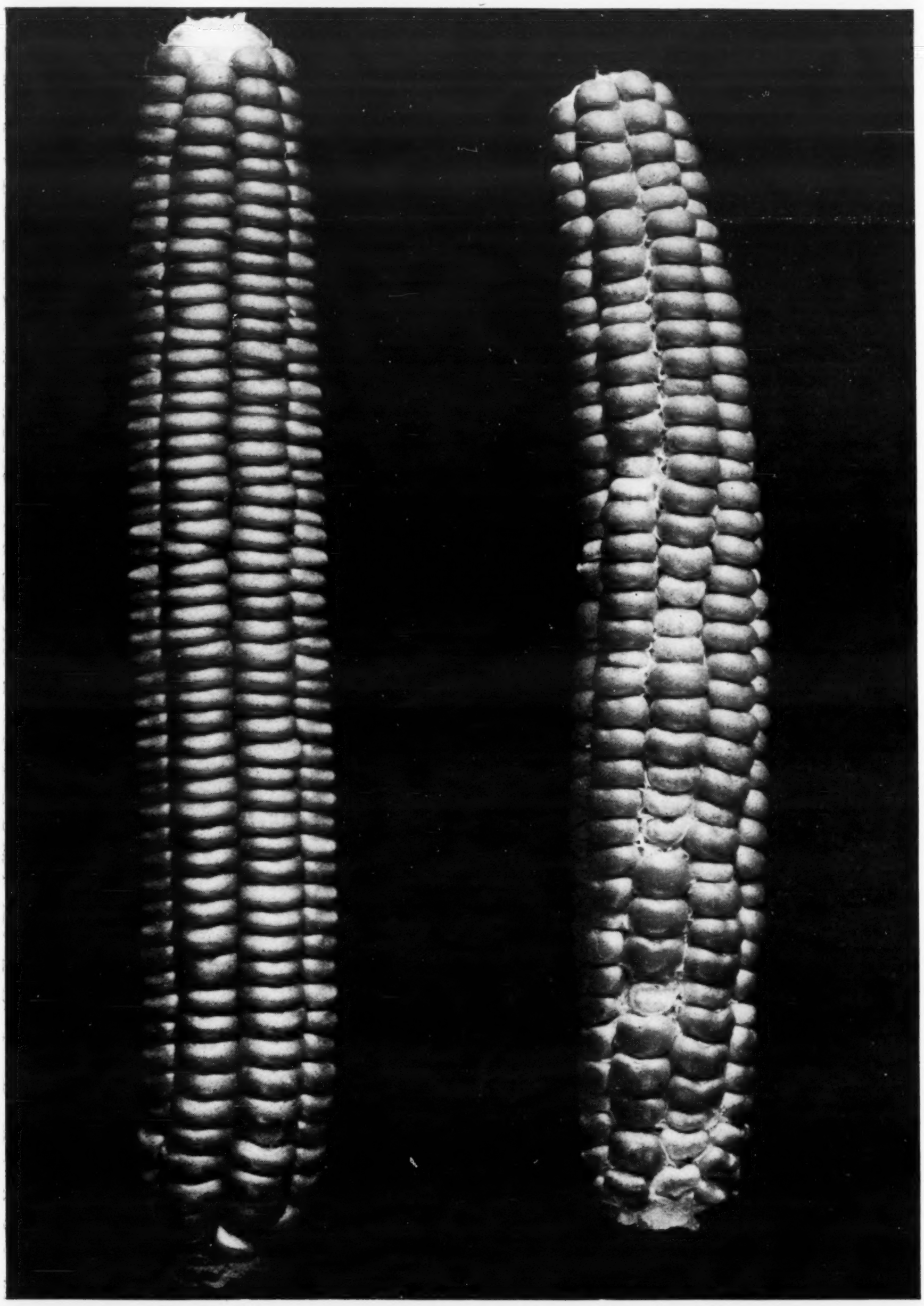
Germinating seeds are just as lethal in action as the other extreme type of defective in which there is no food supply. The aberrant seeds die when the ear is harvested and the moisture supply cut off. It might be possible to transfer the germinating seeds directly to the greenhouse in the fall and mature the character in a homozygous condition during the winter months, but under ordinary field conditions it is a very effective lethal.

Defective Germplasm Wide-Spread

These many types of defective seeds, of which the three here described are typical, are but another example of defective germplasm which may be widespread in any naturally cross-fertilized crop. Almost any field-pollinated ear of corn shows a few defective seeds. Ordinarily, these escape attention, or if noticed, are attributed to the effects of incomplete pollination or other external factors. Some of them no doubt are due to environmental conditions, but many are definitely inherited. It is in the bringing to light of such recessive abnormalities, and in the elimination of inferior germplasm, that inbreeding is of greatest value as a means of permanent improvement.

Genetics in Russia

A LABORATORY of Experimental Zoology and Genetics has been established in Petrograd, under the direction of Professor I. A. Philiptchenko. In Moscow a eugenics society has been organized, which also publishes a bulletin periodically. The cover of this bulletin is ornamented with the portraits of Erasmus Darwin, Charles Darwin and Francis Galton. As Fritz Lenz remarks, in communicating this notice, there is food for thought in the adoption by a Soviet organization of these patrons of science, all three of them representatives of the English landed gentry and owing to inherited wealth their freedom to devote themselves to research in evolution.



Normal Ecar Defective Ear

SEGREGATION OF FLINT-DEFECTIVE GRAINS

FIGURE 16. The normal grains are a dark yellow, while the defective grains are lighter in color and smaller. The germination of the defective grains is very poor, and all that do germinate produce albino plants (see Figure 20). The study of this defect has been rendered difficult because of the sterility of the pollen in this inbred strain. See p. 130.

HERITABLE CHARACTERS OF MAIZE

XIII—ENDOSPERM DEFECTS—SWEET DEFECTIVE AND FLINT DEFECTIVE

E. W. LINDSTROM

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The most outstanding type of defective grain occurred in an inbred strain of the Golden Bantam variety of sweet corn. This variety is noted for its stability of type, not only in its remarkable quality as a table variety of sweet corn, but also in its morphological characteristics. Its deep yellow endosperm, eight-rowed condition, suckering habit and its earliness are all extremely well impressed on the variety.

Inheritance of the Sweet-Defective Type of Endosperm

In 1919 there occurred a single ear among several hundred self-pollinated ears of a commercial variety of Golden Bantam, which showed an unusually sharp segregation of normal and defective kernels. An actual count gave 134 normal and 50 defective grains.

These off-type kernels possessed a small, stunted embryo and about half the usual amount of endosperm. In the roasting-ear stage, the defective kernels were almost as plump as the normal but they showed a peculiar mottling of brown in the endosperm (Figure 17). On drying, they shrink to about half the normal size and are a brownish-gray in color (Figure 18). Samples were given to the plant pathologist for culture to detect any causal organism, but none was found. Germination tests proved that these kernels would not sprout.

The normal grains of the original ear were planted in 1920. The harvest showed a distinct recurrence of the defective grains. Normal grains of this 1920 crop were planted in the following year with a similar result.

The experimental data for these two years have been arranged in Table 1.

Two sorts of progenies were found among all the self-pollinated ears coming from normal grains of a segregating ear. If this hereditary defect is caused by a simple, recessive Mendelian factor, we should expect that one sort would show ears with nothing but normal kernels, while the other sort would comprise ears with seventy-five per cent normal and twenty-five per cent defective grains.

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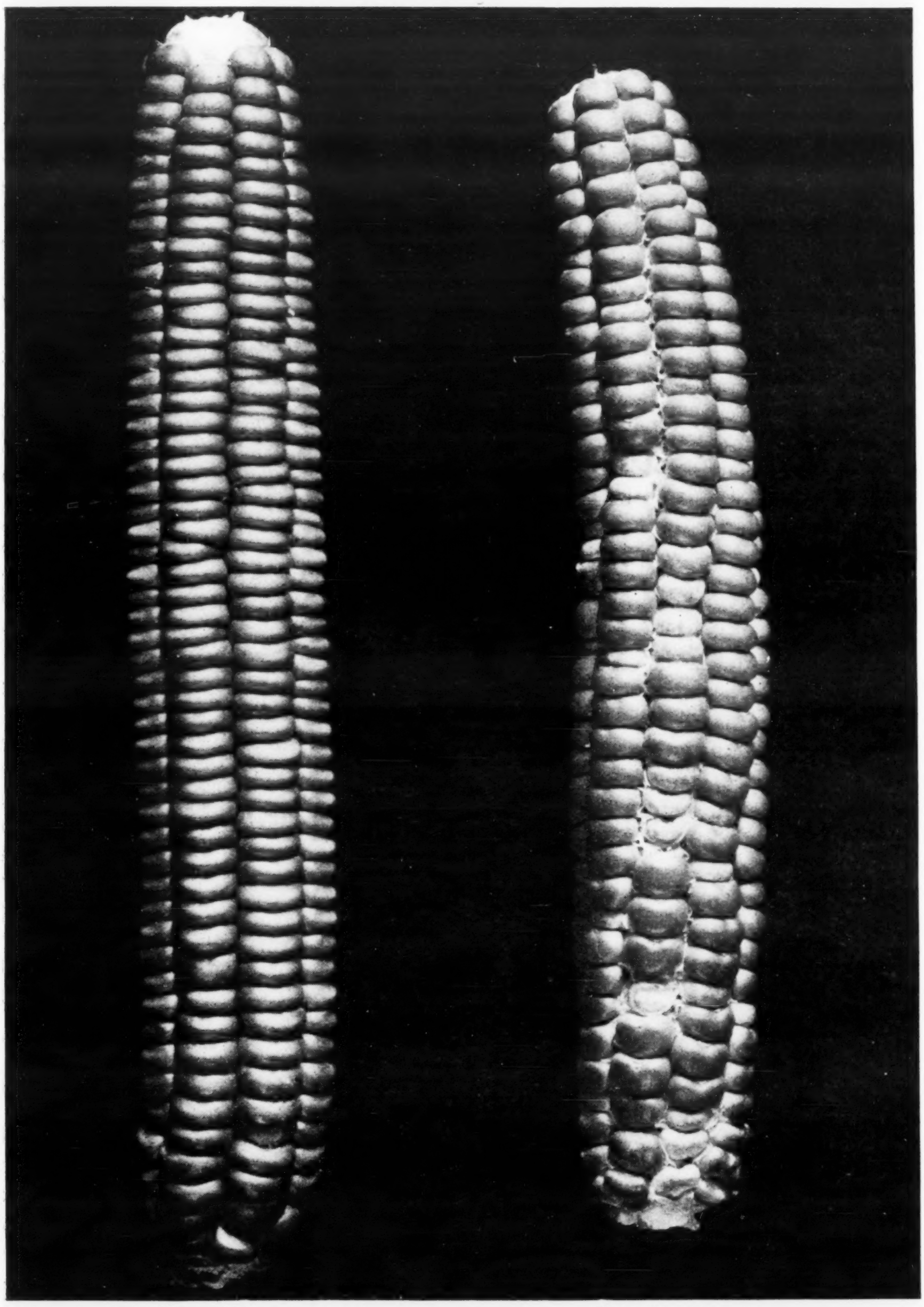

Normal Ear **Defective Ear**

SEGREGATION OF FLINT-DEFECTIVE GRAINS

FIGURE 16. The normal grains are a dark yellow, while the defective grains are lighter in color and smaller. The germination of the defective grains is very poor, and all that do germinate produce albino plants (see Figure 20). The study of this defect has been rendered difficult because of the sterility of the pollen in this inbred strain. See p. 130.

HERITABLE CHARACTERS OF MAIZE

XIII—ENDOSPERM DEFECTS—SWEET DEFECTIVE AND FLINT DEFECTIVE

E. W. LINDSTROM

Iowa State College, Ames.

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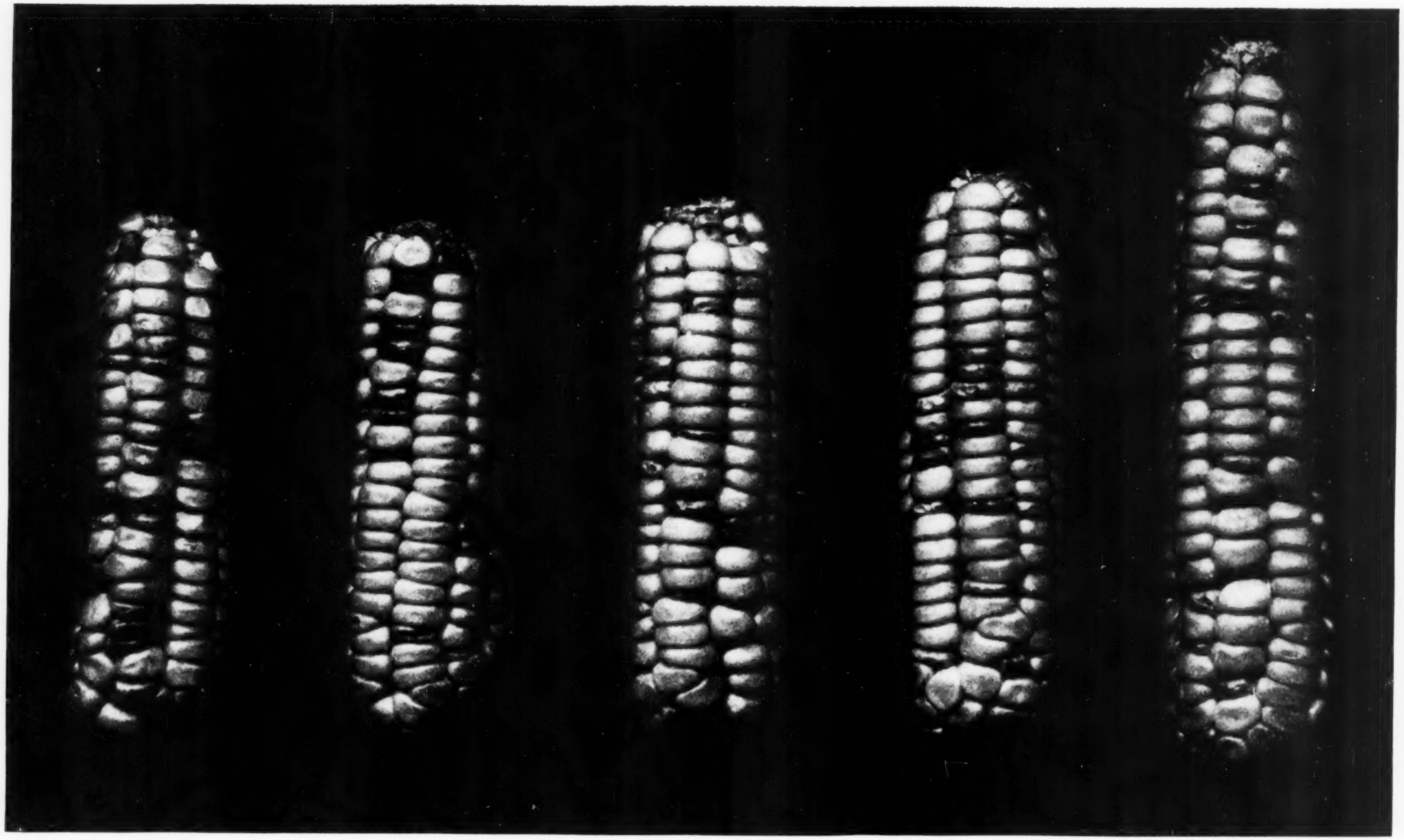

SWEET-DEFECTIVE GRAINS ON IMMATURE EARS OF GOLDEN BANTAM CORN

FIGURE 17. In the roasting-ear stage the defective grains are somewhat smaller than the normal grains, and have a peculiar mottled brown endosperm. The hereditary defects of the endosperm of maize are very numerous, and many distinct kinds have been isolated. Necessarily these defects are recessive, as in nearly all cases they prevent the development of the young plant, and so act as a lethal factor. A dominant defect of the endosperm might appear by mutation, but it would be automatically self-eliminating in the next generation. A recessive defect, however, is masked when in the heterozygous or latent condition, and only appears when pure. Thus these defects are rarely found when maize is cross-pollinated in field culture.

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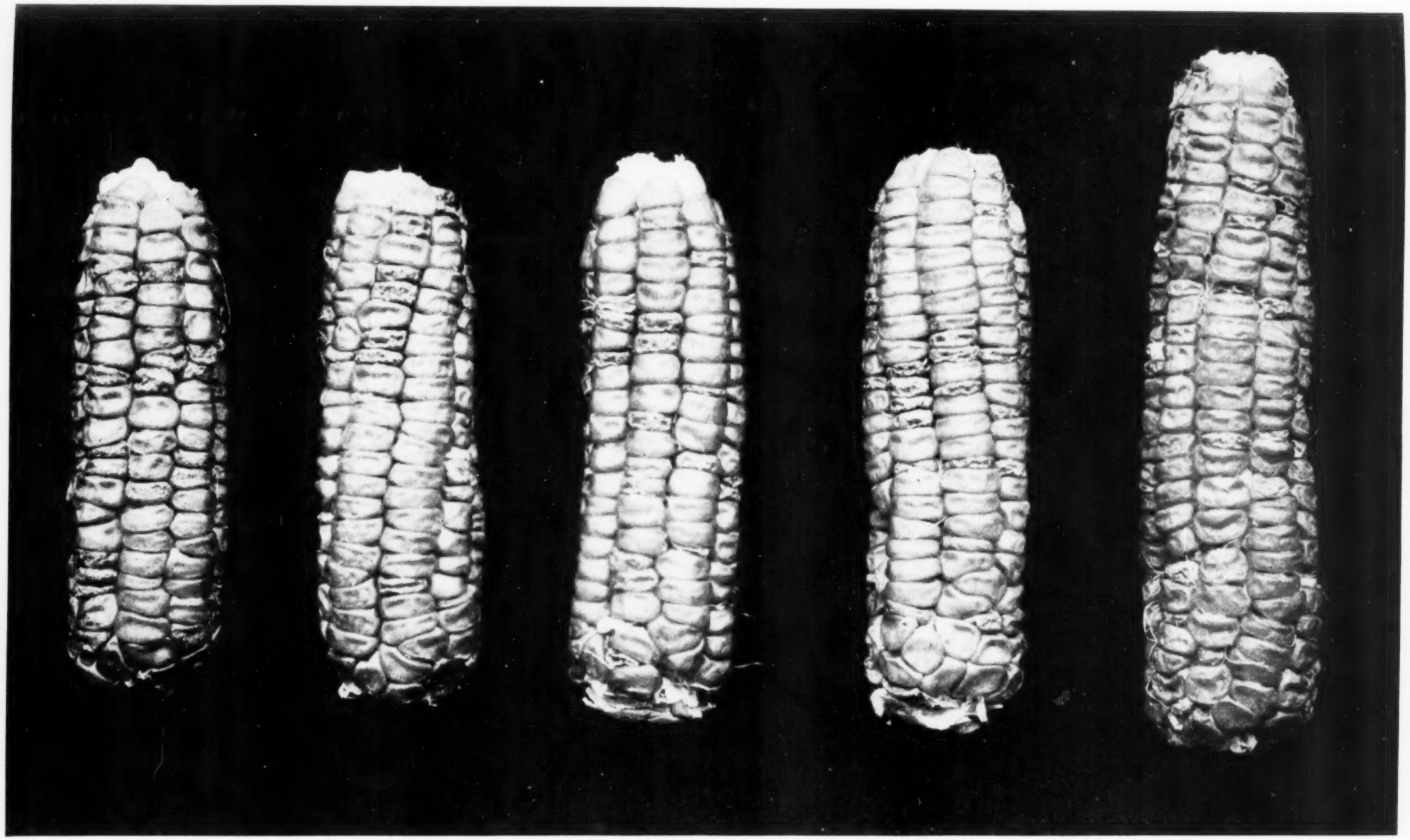


SWEET-DEFECTIVE GRAINS ON DRIED EARS

FIGURE 18. These are the same five ears shown in Figure 17. The defective grains become more wrinkled, since they shrink more than the normal ones, and their color changes to a brownish-grey. The manner of inheritance of this defect was studied in two ways, by counting the number of normal and defective kernels on the ears segregating for the defect, and by a progeny test: plants from the normal grains of segregating ears were self-pollinated, and some were found to segregate for the defect, while others were not. A count of the segregating and non-segregating plants gave a result that almost exactly agreed with theoretical expectation, were the character controlled by a single Mendelian factor, recessive to normal development.

ratios of the individual ears that are heterozygous are in accord with the 3:1 proportion. The total count of thirty-one segregating ears resulted in 4544 normal and 1390 defective grains. There was a slight deficiency of the latter, which may be due to the difficulty of detecting every defective kernel on an ear since some of them are very small and may be easily overlooked. It is entirely possible, however, that this consistent deficiency of the defective kernels may be accounted for by differential pollen tube growth.

However, the best test of the situation is the progeny test, since in this case there is absolutely no difficulty in classifying a normal ear from one that is segregating for the two types of kernels. Such a progeny test appears in Table II.

There were actually fifteen ears with nothing but normal grains and thirty-one with the two kinds of grains. This is as close to the expected results as possible, and it proves that the defective kernel-type of this Golden Bantam variety is controlled by a simple, Mendelian factor.

One of the ears of the last season's harvest (5016-11) presented a very noticeable deviation from all others. It had a higher proportion of defective kernels than any other ear. Besides 112 normal and 44 defective kernels there were 37 kernels that showed a peculiar white appearance (Figure 19). This is especially remarkable since in the three years of inbreeding of this variety, never did any white endosperm occur. These kernels were also of a defective type, but distinctly different from the other. Not only was this new type white in appearance, but there was a marked tendency for the germ to commence growth on the ear. The growth of the embryo consisted mainly of an elongation of the primary root which attained the length of about one-half inch or less within the seed coat. When the grains dried out at maturity the entire embryo turned brown and died. The details of the inheritance of this new type (or mutation) are not known as yet.

Inheritance of the Flint-Defective Type of Endosperm

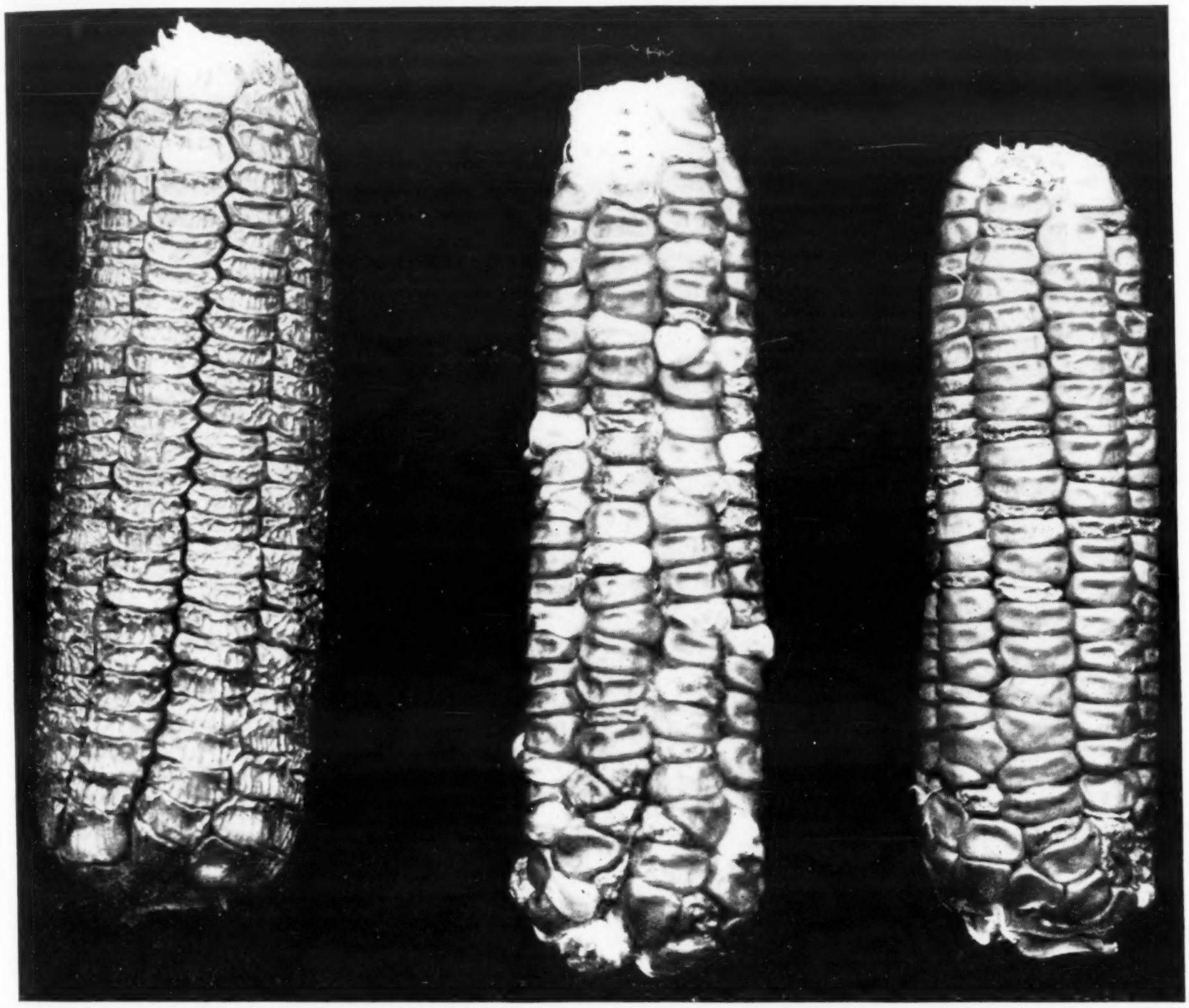
Another type of defective kernel arose in some inbred strains of a yellow flint variety, which originally came from Massachusetts. According to Dr. W. E. Castle who sent the original seed to the writer, the variety name was Stickney, being most likely a selection from Longfellow Flint.

In this case, certain inbred ears exhibited a distinct segregation into normal and defective kernels. The latter are distinctly a pale yellow color, contrasting sharply with the dark yellow color, typical of the variety. This color distinction is enhanced by the difference in endosperm texture. While the normal seeds are characteristically hard and flinty, the defective kernels are dull and starchy in appearance, and somewhat smaller in size (Figure 16).

The germination of the defective kernels is very poor. But the striking thing is that whenever they do germinate, they produce white or albino seedlings. The photograph (Figure 20) of the seedling flat shows the situation very well. When the normal seeds of the segregating ear are planted separately from the defective kernels, the former produce green seedlings while the latter throw pure whites. The alternate rows in the flat show this very distinctly.

A study of the inheritance of this flint-defective endosperm has been rendered very difficult by reason of a large amount of pollen sterility in this inbred strain. Self-pollinated ears are obtained only with great difficulty. Cross-bred ears are easily made, showing that the ovules are fertile.

The original ear (2258-5) showing this abnormal endosperm characteristic was one of a large family that was heterozygous for white and pale yellow seedlings, which were in every way typical of the ordinary seedlings showing such chlorophyll defects. This fact



Normal Ear Segregating for the New Defect Segregating for Sweet Defective

DEFECTIVE KERNEL TYPES IN INBRED GOLDEN BANTAM SWEET CORN

FIGURE 19. In addition to the sweet-defective endosperm studied for two generations in this inbred strain, another entirely distinct defect appeared in the third generation, remarkably similar to that described by Mangelsdorf in another variety of sweet corn (see Figure 13). In this case the appearance of the defect would seem to be due to mutation, as it was absent in the preceding inbred generations. (See page 130.)

leads us to suppose that the white seedlings so closely associated with the defective kernels are genetically identical with the ordinary type and are not fundamentally due to the defect in the kernel itself. Scores of crosses were attempted to check this, but the sterility involved in this variety prevented any success.

The inheritance of this defective endosperm character was studied by means of planting the normal grains of self-pollinated ears that were segregating for normal and defective kernels. The individual plants arising from such normal kernels were in turn self-pollinated. This was done for two growing seasons. Counts of thirty ears thus produced are presented in Table III.

Of these thirty ears, six showed no defective grains (from homozygous normal seeds), and twenty-four had both normal and defective grains on the ear (from heterozygous seeds). If the genetic factors governing the inheritance of this allelomorphic pair (normal-defective) of characters is a simple one, we should expect a proportion of ten homozygous to twenty heterozygous

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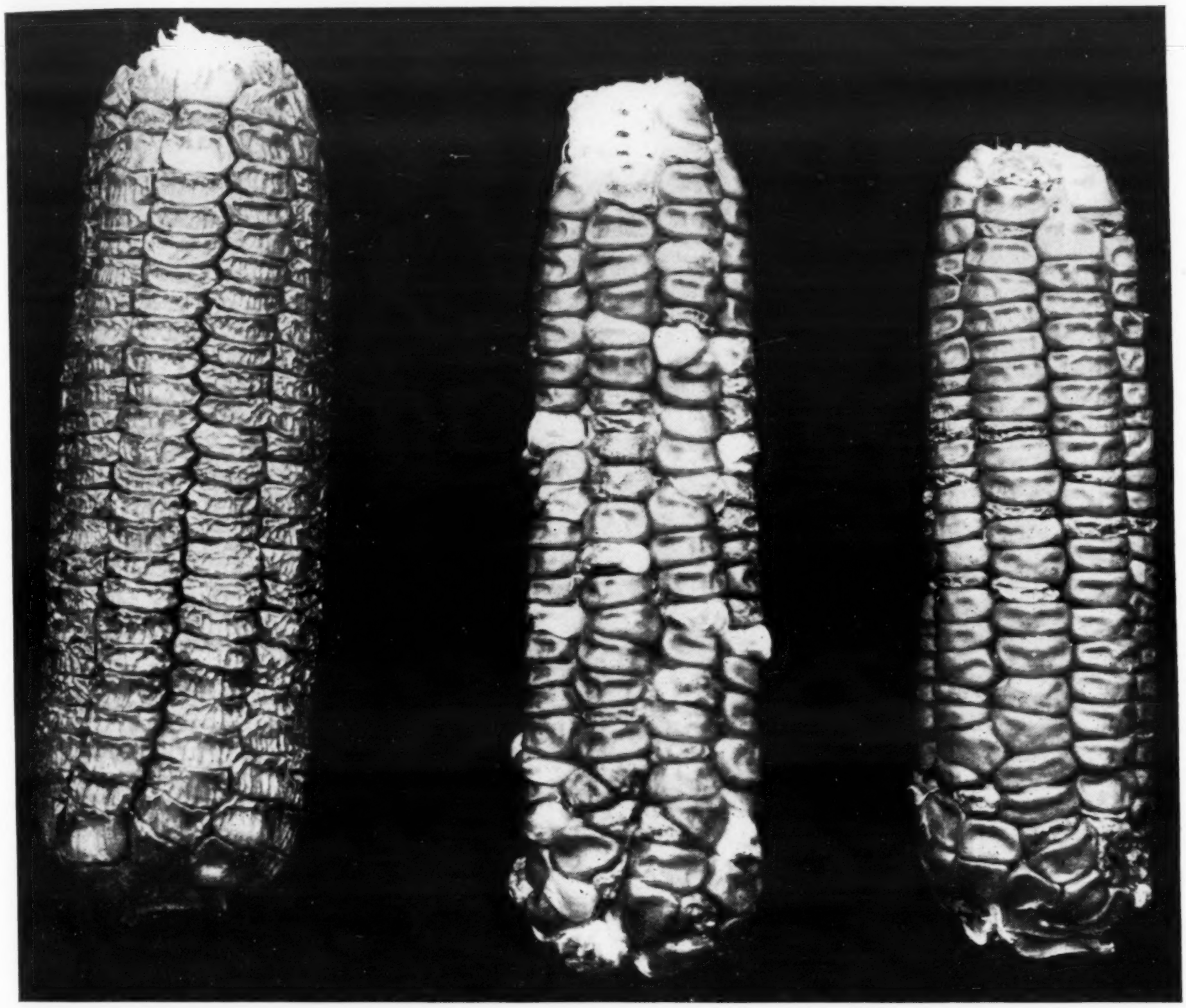

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ears instead of six and twenty-four, as was actually the case. This is not an especially close approximation to theory, although the deviation (4) is only 2.3 as large as the probable error.

Some of the individual ears that segregated for the two kernel types exhibit considerable deviation from a 3:1 ratio. This was noticeably true of the poorer ears which always seemed to possess less than twenty-five per cent. defective kernels. The better developed ears, those with the larger number of kernels, do not depart very greatly from the expected 3:1 proportion, although there is still a slight deficiency of the defective kernels. The total of all the ears approaches a 3:1 ratio, but in this case the deficiency of defective kernels in the poorly developed ears is magnified. However, the totals are not entirely beyond the limits of a simple, single-factor hypothesis.

The seedling data from the thirty self-pollinated ears show one or two points of interest. In the first place, all the ears that were normal in endosperm (total of six) produced not a single white seedling. This fact is a strong indication that there is a complete association, correlation, or linkage between green seedlings and normal endosperm (or white seedlings and defective endosperm). Otherwise we might expect occasionally a normal ear to produce three green to one white seedling, as was the case in the original grand-parental stock.

The seedling progenies from the twenty-four ears that possessed both normal and defective kernels exhibit some interesting facts (Table IV). In every case the normal grains from such ears were planted separately from the defective ones. The percentage of germination of the latter was very poor. A noteworthy fact is that the second generation progenies (pedigree numbers 4122, 5009 and 5010) showed a far smaller per cent. of germination than the original ear and the first generation from it (3354). The reason for this is unquestionably due to the fact that the mother ears of the second generation were those chosen because of the distinctness of their defective kernels. This means that a smaller defective kernel type was selected, which gave a progeny that reproduced this characteristic, thereby possessing less endosperm and less ability to germinate.

A glance at Table IV shows at once that the seedlings coming from normal grains of heterozygous ears were green in the great majority of cases. Conversely those coming from defective seeds were white, with a few exceptions.

In the first generation from the original ear a greater number of exceptions occur than in the second generation (pedigree numbers 5009 and 5010 especially). For this reason it is logical to suppose that the exceptions noted can most easily be attributed to mistakes in classifying the grains into normal and defective. Where this classification is more distinct, as is the case in later progenies (5009 and 5010), the exceptions are very rare. Accordingly it seems plausible that the so-called exceptions are not due to genetic crossovers of the linkage between the chlorophyll and endosperm factors involved. This may be a case of a very close but not complete linkage, although that does not seem very reasonable.

These two types of abnormal kernels, the sweet-defective and flint-defective, are distinctly different from the abortive type reported several years ago.[1] In the abortive type there is a complete failure of endosperm development. Both the defective and abortive types have been found in several inbred strains of dent corn. Apparently these are similar to those reported by Jones.[2] There appear to

[1] Lindstrom, E. W. Chlorophyll Factors of Maize. *Journal of Heredity*, **11**:269-277. 1920.

[2] Jones, D. F. Heritable Characters of Maize, IV. A Lethal Factor—Defective Seeds. *Journal of Heredity*, **11**:161-167. 1920.

SEEDLINGS FROM FOUR SELF-POLLINATED EARS SEGREGATING FOR FINT DEFECTIVE KERNELS, SHOWING LINKAGE

FIGURE 20. When the defective grains of flint corn (Figure 16), are grown separately from the normal grains from the same ear, a striking difference appears in the seedlings. Above are shown alternate rows of seedlings from normal grains, and from flint-defective ones. All those from defective seeds have produced albino plants. Relatively very few of the defective seeds have sprouted, and even at this early stage the albino seedlings are evidently at a disadvantage as compared with the normal ones. As the plants grow older the difference will become greater. The albinos eventually will starve to death, as the absence of chlorophyll makes it impossible for them to manufacture food from sunlight and the elements drawn from air and soil.

be several different genetic types of defective and abortive endosperm. It so happens that this material does not exhibit such clean-cut types as those reported in this article. Another year's work, in which the secondary modifiers influencing the kernel type are rendered pure, is necessary.

Recent work is proving that the endosperm of maize is but another example of a qualitative, heritable character that is dependent on a large number of genetic factors for its development. Besides the factors that control the physical texture of the endosperm such as the sweet, flint, dent, pop, floury and waxy factors, we must now add at least a half-dozen others that control directly the formation and complete development of the endosperm itself. The recessive allelomorphs of these might be classed as lethal or semi-lethal factors for endosperm development.

The general situation is similar to that of another characteristic of the corn plant. Chlorophyll, for example, is a distinct genetic character that is now known to involve at least twenty separate genetic factors, ranging from

those that are completely lethal (such as produce white seedlings) to those that are non-lethal, producing merely a pale or light green plant. These discoveries are pointing clearly to the fact that while the hereditary units (factors or genes) themselves are apparently discontinuous units or entities, they are so numerous and often their effects are so minute that they appear to present a continuous series when viewed as a whole. But inasmuch as we can isolate and study any one of these numerous factors, their actual unity is proven when they fall into a definite system of heredity, as they actually do.

Summary

An endosperm defect in sweet corn, called sweet-defective, which arose in an inbred Golden Bantam strain is proven to be inherited as a simple, Mendelian recessive.

A distinct mutant involving another endosperm defect arose in the third inbred generation of the Golden Bantam strain. Evidence indicates that this could not have been in the stock in previous years.

Another recessive endosperm defect was discovered in yellow flint corn. This flint-defective type shows complete linkage with albino seedlings.

TABLE I—*Showing progenies from normal kernels of self-pollinated ears that were segregating for sweet-defective grains.*

Pedigree No. of Selfed Ear	Normal	Defective
Original Ear	134	50
4264-5	all	..
4264-7	117	38
4264-8	all	..
4264-11	135	37
4264-14	120	30
4264-17	87	24
Sub-total	459	129
Theoretical	441	147
5015-1	148	41
5015-2	178	71
5015-3	all	..
5015-4	all	..
5015-5	171	52
5015-6	all	..
5015-7	all	..
5015-8	131	39
5015-9	all	..
5015-16	162	68
5015-18	179	51
5015-19	150	48
Sub-total	1119	370
Theoretical	1117	372
5016-1	all	..
5016-3	all	..
5016-4	139	44
5016-5	121	48
5016-6	all	..
5016-8	123	31
5016-9	all	..
5016-10	147	48
5016-11	149	44
5016-12	180	55
5016-13	139	38
5016-14	all	..
5016-15	148	43
Sub-total	1146	351
Theoretical	1123	374
5017-1	all	..
5017-2	207	57
5017-3	all	..
5017-4	143	44
5017-5	135	38
5017-6	159	45
5017-7	121	43
5017-8	141	48
5017-9	116	35
5017-11	174	49
5017-12	152	44
5017-14	all	..
5017-15	146	47
5017-18	192	40
Sub-total	1686	490
Theoretical	1632	544
Grand Total	**4544**	**1390**
Theoretical	**4451**	**1484**

TABLE II. *Showing proportion of homozygous and heterozygous genotypes tested by progenies derived from self-pollination.*

Pedigree No. Mother Plant	Pedigree No. of Progeny	No. Progenies That Were Homozygous	Heterozygous
Golden Bantam selfed.....	4264	2	4
Golden Bantam selfed.....	5015	5	7
4264-11	5016	5	8
4264-14	5017	3	12
Total		15	31
Theoretical		15.3	30.7

TABLE III. *Showing self-pollinated progenies from normal grains of ears that segregated for normal and flint-defective kernels.*

Pedigree No. of Selfed Ear	Normal	Defective	Origin
3354-1	189	60	From
3354-2	119	23	2258-5
3354-5	228	68	
3354-9	all	..	
3354-10	162	55	
Sub-total	698	206	
Theoretical	678	226	
4122-2	187	66	From
4122-6	34	11	3354-1
4122-11	78	19	
4122-18	40	8	
4122-24	47	9	
Sub-total	386	113	
Theoretical	364	125	
5009-3	75	17	From
5009-4	227	70	3354-1
5009-5	all	..	
5009-10	94	22	
5009-13	230	69	
5009-17	208	80	
5009-18	93	25	
5009-20	217	50	
5009-21	all	..	
5009-23	264	81	
5009-25	124	30	
5009-26	223	89	
5009-27	all	..	
5009-28	155	30	
Sub-total	1910	563	
Theoretical	1855	618	
5010-1	234	84	From
5010-8	196	66	4122-2
5010-9	191	65	
5010-13	all	..	
5010-17	225	74	
5010-24	all	..	
Sub-total	846	289	
Theoretical	851	204	
Grand Total	**3840**	**1171**	
Theoretical	**3759**	**1253**	

TABLE IV. *Results of seedling progeny tests from self-pollinated ears showing the linkage between white seedlings and flint-defective grains.*

Pedigree No. of Selfed Ear	From Normal Grains *Green*	*White*	From Defective Grains *Green*	*White*
3354-1	150	1	0	18
3354-2	69	2	0	18
3354-5	186	10	1	66
3354-10	113	2	6	25
Sub-total	518	15	7	127
4122-2	118	0	0	7
4122-6	27	0	0	4
4122-11	43	3	0	8
4122-18	23	1	0	3
4122-24	33	0	0	3
Sub-total	244	4	0	22
5009-3	14	0	0	1
5009-4	26	0	0	0
5009-10	20	0	0	0
5009-13	20	0	0	4
5009-17	27	0	0	0
5009-18	10	0	0	2
5009-20	15	0	0	0
5009-23	20	1	0	6
5009-25	25	0	0	0
5009-26	26	0	0	0
5009-28	23	0	0	0
Sub-total	226	1	0	13
5010-1	25	0	0	0
5010-8	23	0	0	0
5010-9	11	0	0	0
5010-17	32	0	0	2
Sub-total	91	0	0	2

INTERNAL SECRETIONS AND ACQUIRED CHARACTERS

A Review

HORMONES AND HEREDITY, by J. T. CUNNINGHAM. Pp. xx + 246. New York. The Macmillan Company. 1921.

While the chief object of the volume is, in the author's words, "to discuss the relations of modern discoveries concerning hormones or internal secretions to the question of the evolution of adaptations, and on the other hand to the results of recent investigations of Mendelian heredity and mutations," it reviews a wide range of subjects, many of which are but remotely if at all connected with hormones. Thus, the following topics are discussed: Historical Survey of Theories or Suggestions of Chemical Influences in Heredity; Classification and Adaptation; Mendelism and the Heredity of Sex; Influence of Hormones in Development of Somatic Sex-characters; Origin of Somatic Sex-characters in Evolution; Mammalian Sexual Characters; Evidence Opposed to the Hormone Theory; Origin of Non-sexual Characters; The Phenomena of Mutation; Metamorphosis and Recapitulation.

From time to time throughout the work an irascibility is evinced toward Mendelism, but just why, one is unable to determine from any analysis submitted in the text. The supposed difficulties mentioned appear to the reviewer, at least, to be largely false issues which are adequately accounted for by the modern factorial hypotheses of Neo-Mendelists. Various of the other difficulties which are cited by the author as outstanding, have been discussed and shown to be at least not necessarily in disharmony with Mendelism by Morgan, in his *Heredity and Sex,* published in 1913—a volume with which Cunningham appears to be unacquainted.

The book, in the main, is an elaboration and defense of the author's earlier Lamarckian theory of the origin of secondary sexual characters in relation to hormones, although the theory is extended to other adaptive structures and to certain types of non-sexual characters. His central idea appears to be that any over- or under-production of hormones may stimulate the appropriate "determinants" in the genital cells and modify them correspondingly. The author avows his adherence to the idea of continuous variation (fluctuations) in the Darwinian sense as distinguished from mutations, but apparently his conception of mutations is the older one which regards them as changes of considerable magnitude, rather than the modern one which admits of any degree of minuteness. Recognizing as do all modern naturalists that the origin of species and the origin of adaptations respectively are two distinct problems, he attempts to account for the latter on the basis of hormonic influences.

In his own words:

> My view is, then, that specific characters are usually not adaptations, that other characters of taxonomic value are some adaptive and some unrelated to conditions of life, and that while non-adaptive characters are due to spontaneous blastogenic variations or mutations, adaptive characters are due to the direct influence of stimuli, causing somatic modifications which become hereditary, in other words, to the inheritance of acquired characters.

Since, to do justice to the author's ideas it seems safest to set them forth in his own phraseology, the reviewer has chosen the following representative passages which indicate the trend of the argument.

> The fact that a hormone from the testis affects the development of the antler, as well as our knowledge of hormones in general,

suggests a special theory of the heredity of somatic modifications due to external stimuli. Physiologists are apt to look for a particular gland to produce every internal secretion. But the fact that the wall of the intestine produces secretion, which carried by the blood causes the pancreas to secrete, shows that a particular gland is not necessary. There is nothing improbable in supposing that a tissue stimulated to extensive growth by external irritation would give off special substances to the blood. We know that living tissues give off waste products, and that these are not merely pure CO_2 and H_2O, but complicated compounds. The theory proposed by me in 1908 was that we have within the gonads numerous gametocytes whose chromosomes contain factors corresponding to the different parts of the soma, and that these factors or determinants might be stimulated by waste products circulating in the blood and derived from the parts of the soma corresponding to them. There is no reason to suppose that an exostosis formed on the frontal bone as a result of repeated mechanical stimulation due to the butting of stags would give off a special hormone which was never formed in the body before, but it would probably in its increased growth give off an increased quantity of intermediate waste products of the same kind as the tissues from which it arose gave off before. These products would act as a hormone on the gametocytes, stimulating the factors which in the next generation would control the development of the frontal bone and adjacent tissues.

The difficulty of this theory is one which has occurred to biologists who have previously made suggestions of a connexion between hormones and heredity—namely, how hormones or waste products from one part of the body could differ from these from the same tissues in another part of the body. If there were no special relation, hypertrophy of bone on one part of the body such as the head would merely stimulate the factor for the whole skeleton in the gametocytes, and the result would merely be an increased development of the whole skeleton. On the other hand, we have the evident fact that a number of chromosomes formed apparently of the same substance, by a series of equal chromosome divisions determine all the various special parts of the complicated body. This is not more difficult to understand than that every part of the body should give off special substances which would have a special effect on the corresponding parts of the chromosomes. We know that skin glands in different parts of the body produce special odors, although all formed of the same tissues and all derived from the epidermis. It seems not impossible that bones of different parts of the body give off different hormones. If the factors in the gametes were thus stimulated they would, when they developed in a new individual, produce a slightly increased development of the part which hypertrophied in the parent soma. No matter how slight the degree of hereditary effect, if the stimulation was repeated in every generation, as in the case of such characters as we are considering it undoubtedly was, the hereditary effect would constantly increase until it was far greater than the direct effect of the stimulation.

Again, referring to the origin of the phenomena of the shedding and regrowth of antlers, he has this to say:

The annual shedding and recrescense of the antler, however, is only to be understood in connection with the effect of the testicular hormone. According to my theory there are two hormone actions, the centripetal from the hypertrophied tissue to the corresponding factor in the gametocytes, and the contrifugal from the testis to the tissue of the antler or other organ concerned. The reason why the somatic sexual character does not develop until the time of puberty, and develops again each breeding season in such cases as antlers, is that the original hypertrophy due to external stimulation occurred only when the testicular hormone was circulating in the blood. The factor in the gametocytes then was in each generation acted upon by both hormones, and we must suppose that in some way the result was produced that the hereditary development of the antler in the soma only took place when the testicular hormone was present. It is to be remembered that we are unable at present to form a clear conception of the process of development, to understand how the simple fertilized ovum is able by cell-division and differentiation to develop into a complicated organism with organs and characters predetermined in the single cell which constitutes the ovum. If we accept the idea that characters are represented by particular parts of the chromosomes, according to Morgan's scheme, our theory of development is the modern form of the theory of preformation. When in the course of development the cells of the head from which the antlers arise are formed, each of these cells must be supposed to contain the same chromosomes as the original ovum from which the cells have descended by repeated cell-division. The factors in these chromosomes corresponding to the forehead have been stimulated while in the parent animal by hormones from the outgrowth of tissue produced by external mechanical stimulation, while at the same time they were permeated by the testicular hormone produced either by the gametocytes themselves or by interstitial cells of the testis. When the head begins to form in the process of individual development, the factors, accord-

ing to my theory, have a tendency to form the special growth of tissue of which the incipient antler consists, but part of the stimulus is wanting, and is not completed until the testicular hormone is produced and diffused into the circulation—that is to say, when the testes are becoming mature and functional.

I do not claim that this theory is complete—it is impossible to understand the process completely in the present state of knowledge—but I maintain that it is the only theory which affords any explanation of the remarkable facts concerning the influence of the hormones from the reproductive organs on the development of secondary sexual characters, while at the same time explaining the adaptive relation of these characters or organs to the sexual habits of the various species.

The author makes various digressions from time to time to show how, in his opinion, various adaptive features can have arisen as a result of Lamarckian factors. The explanations suggested are invariably ingenous and interesting, if not always convincing. He uses the term hormone, it should be pointed out, in a much broader sense than is warranted by our actual knowledge, inasmuch as indisputable evidence of the existence of such internal secretions is as yet confined to the products of relatively few organs.

The book is too diverse in its scope to permit of concise summarization. As a whole, it is an interesting discussion, interspersed with bits of information which are of value to biologists, particularly those interested in the problems of evolution, individual development, and secondary sexual characters.

It will be difficult, indeed, for the author to persuade the majority of geneticists today that (p. 55), "The Mendelian theory is merely a theory in words, which have an apparent relation to the facts, but which when examined, do not correspond to any real conceptions," or to lead them to believe (p. 129) that, "There is a tendency among Mendelians and mutationists to overestimate the importance of experiments in comparison with reasoning, either inductive or deductive."

To the reviewer, the grounds advanced for the author's theory are suggestive rather than conclusive, and they will doubtless remain so for many biologists until more definite experimental evidence is forthcoming.

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For Those About to Marry

Die Gattenwahl, ein artzliches Ratgeber bei der Eheschliessung, by Dr. Max Hirsch. Pp. 42. Price, 20c. Leipzig, Curt Kabitsch Verlagsbuchhandlung, 1922.

Dr. Hirsch, editor of the Archiv fur Frauenkunde und Eugenetik, has attempted the useful task of furnishing in a brief and simple form such information regarding hereditary defects and infectious diseases as might be useful to one about to marry. Besides describing the bearings on marriage of the principal physical and mental maladies, he considers such related subjects as alcoholism. A concluding section urges on all candidates for marriage the desirability of a thorough medical examination. A similarly practical and inexpensive booklet in the English language ought to be available.—*P. P.*

THE ALLEGHENY COLLEGE BIRTH RATE

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(Continued from the May Number)

THE difference in family size per married alumnus in the two periods is .29 ± .20 children. A chance difference of this magnitude will occur 33 times out of every 100. The difference is therefore not statistically significant; it may have been due to chance. It should be recalled, however, that the living graduates in the period 1870-1884 are a more highly selected group from the standpoint of length of life than those in the period 1885-1899. Therefore the average fecundity in the earlier group may have been higher than that in the later one, because the long-lived men have the larger families. Had both groups been equally selected for longevity, the difference in family size might have been still less.

The difference between the two periods in the average number of children per male graduate is .30 ± .19. This difference is likewise not significant statistically. But married alumni with incompletely reported families have been excluded in Table 5. If the number of unmarried individuals in this computation is reduced so that the percentage of unmarried is the same as in the whole data derived from the questionnaire (8% and 11% for the periods 1870-1884, 1885-1899, respectively), then the two averages will be 2.69 (1870-1884) and 2.36 (1885-1899). The percentage of married individuals among the women graduates reported in the questionnaires is not far, it will be recalled, from the percentage among all the women graduates as reported in the Alumni Register. This was true whether reporting women with incompletely reported families be excluded or included in making the computation. In other words, the questionnaire provided a fair sample of the women as far as the proportions of married and unmarried persons were concerned. Our sample of men is therefore probably representative in the same respect. All available data, therefore, indicate that the numbers of unmarried men we have used in computing the "Children per male graduate" in Table 5 are not far from what they would have been had accurate determinations of percentages of married men in the whole body of graduates been available for use.

The data shown in Table 5 do not meet all the requirements of a rigorous analysis. If the wife is now dead or divorced, the alumnus may marry again and have more children by the second wife. In cases where the wife is less than forty-five years of age, the family may yet increase in size because the mother is still capable of bearing children. The averages in Table 6 are based on families in which (1) the husband (a graduate) is dead (13 cases), and (2) families in which both husband (a graduate) and wife are living, but the wife is not divorced and is 45 years old or older.

The difference between the mean number of children of married alumni in the two periods is .24 ± .22. This difference is not statistically significant. It may have been due to chance. Had the two groups been subjected for equal lengths of time to lethal selection, the difference might have been even less, as pointed out for Table 5.

The divergence between the average numbers of children per male graduate, .29 ± .22, is likewise not statistically significant. The percentages of unmarried persons used in making these computations are the same as in the whole data obtained in the question-

naires for the two periods. If the ratio between the married and the unmarried persons used in the computations be made the same as in Table 5, the averages are 2.63 children (1870-1884), and 2.36 (1885-1899).

It is clear that there has not been a considerable or significant decrease in the size of the families within the group studied.

The Families of Clergymen

The Allegheny College statistics furnish a limited opportunity for a study of the families of clergymen. The College has always been strongly religious. Many of its alumni are ministers. Some of them hold, and have held, high offices in the Church. Table 7 summarizes the data for these men. There are college presidents, a Y. M. C. A. worker, a missionary, and so forth, but all except eight are known to have been actively engaged in the Christian ministry. Of the married individuals, only those are tabulated whose total number of children to date, dead and living, was furnished by the questionnaires.

A second computation of the average number of children per family was made, discarding all cases where the wife is dead or younger than 45 years. The average for the earlier period was 4.7 children (19 families), and 3.1 (25 families) for the later period.

Compare Table 7 with Tables 3, 5 and 6. The most striking feature brought out by this comparison is the somewhat larger size of minister's families, especially for the classes of 1870-1884. The superiority of the clergymen almost disappears, however, in the second period. The drop in the size of the families by an average of over one and a half children each, suggests that voluntary limitation came into vogue among the individuals of the later period.

c. The third and most important question is, has the group under observation produced enough children to replace itself? Will the number of children who reach early manhood, the approximate age at which their parents graduated from college, be less, equal to, or greater than the total number of parents plus their unmarried classmates?

Many of the children of the earlier graduates are doubtless middle-aged by this time, but on the other hand a considerable number of the offspring of the later graduates are probably still young children. Therefore, direct observations on these children would not furnish a satisfactory answer to this question.

The nearest approach to an accurate answer is found by employing a mortality table. In such a table a hypothetical number of individuals (10,000 or 100,000 for instance) is represented as starting life, say at 0 age. The probable number that will survive death is then shown for each succeeding year until extreme old age. I have employed the Northeastern States Mortality Table.[17] The data used in constructing this table were "the death returns for the five calendar years 1908-1912, inclusive, and the census returns as of June 1, 1900, and April 15, 1910, for the New England States and the three Middle Atlantic States, New York, New Jersey, and Pennsylvania." It will be observed that this table is a recent one covering the territory in which a very large part of the graduates have lived.

The numerical maintenance of this limited section of the population obviously depends not only upon the replacement of the parents (one or both of whom in each family is a graduate of Allegheny College), but also of the unmarried classmates of the parents. A few of the men (14) married women graduates. These women are counted among the wives of the male graduates and not under the heading of women graduates in Tables 8 and 10. Thus they are not counted twice. Whenever a male alumnus married a second time, the second wife is, of course, counted as one of the parental group.

The children indicated in Table 8 are from only those families where the total number of children to date (living and dead) was given on the questionnaires.

The number of children computed to be the survivors at 23 years, the approximate average age at which their parents graduated (Table 3), is fifty-nine less than the parental group. This number of survivors at twenty-three years is only ninety-one per cent. of the parental group.

Compare this with the record of the ministerial graduates, Table 9.

The ministerial group, with its relalatively high marriage and birth rates, is apparently increasing, for the camputed number of children surviving at age of twenty-three years is thirty-six per cent. *in excess* of the parental group. The birth rates in Table 7 should be consulted in connection with Table 9. There is no apparent reason for believing that the clergymen as a group have been naturally more fertile than the other alumni. Conscientious scruples, entirely praiseworthy in the main, may have prevented them from using contraceptive measures to the same extent as the other graduates. It should be noted, however, that the size of the family shows an abrupt decrease in the second period.

I suspect that a real process of natural selection has been operating here. The minister, more altruistic and with greater faith in the future than his schoolmates, has ventured to rear more children, even on an inadequate salary. The writer is not aware that love of children, altruism, or any other characteristics that would lead to the desire for a large family, are inherited; but if they are inheritable the greater reproductive rate of the ministers may be eugenically significant. Surely, it would be fortunate if the higher moral qualities could be disseminated in a race by the extinction of selfish strains through excessive birth control, and a corresponding increase in altruists.

Some of the families represented in Table 8 will doubtless be augmented. A part of the women there have not reached the end of the reproductive period. The families in Table 10 are complete, as far as can be determined. The families of male graduates are confined to those in which (1) the husband is dead, or (2) both husband and wife are living, but the wife is not divorced and is 45 years old or older. Obviously a widower or divorced man could marry a woman young enough to bear children. The number of unmarried men has been reduced so that the ratio between married and unmarried is the same as in Table 8; the same is true for the women.

The number of offspring computed as survivors at the age of twenty-three is, curiously, ninety-one per cent. of the parental group here also.

This percentage is probably too low, for the following reasons. These children came from parents who were longer-lived, on the average, than the complete body of graduates from 1870-1899. The rather unusual vigor of the parents, manifesting itself as corresponding extension of life, has doubtless been transmitted to some extent to their children. Therefore it may be that these children have the capacity for living longer, on the average, than even the population from which the Northeastern States Mortality Table was computed. But it is hard to believe that the survivors at the age of twenty-three years would much exceed the parental group numerically. The total number of children at birth was only seventeen or eighteen per cent (Tables 8 and 10) in excess of the parent group. The great mortality of infancy (nearly thirteen per cent. during the first year of life, ordinarily) would surely greatly reduce this excess.

A study of the reporting graduates of the classes from 1890-1899 furnishes confirmatory, though by itself inconclusive, evidence in favor of the view that the group of graduates

about whom we have gathered complete information has hardly more than replaced itself. There were 126 men in this decade whose total number of children to date, living and dead, were reported. There were nineteen single men. The married men had been married an average of 22.7 years when the information was collected. This parental group of 271 persons (husbands, wives, and single men) had 279 surviving children. The latter exceeded the former by three per cent. The average age of the children is not known, but it is probably considerably less than the above average duration of the married period. That is, the mean age of the children is doubtless less than twenty-three years. The slight excess (3 per cent.) in the number of children above the parental group will undoubtedly be lowered or obliterated by the time the average age reaches twenty-three years.

If only those families (70 in number) are considered in which future child bearing is improbable or impossible, the surviving children (161) exceed the parental group (husbands, wives, and a proportionate number of single men) by only 6.6 per cent. The average duration of married life in these cases was 25.3 years.

The ages of the fifteen women graduates of the decade 1890-1899 show that their families will doubtless not increase. All but one (43 years old) have reached or passed their forty-fifth year. There are only twenty-two surviving children, scarcely half the number (45) of the parental group (husbands, wives, and single women).

Conclusion

I believe the facts justify the following conclusions. (1) The *selected group* of graduates I have studied will raise to maturity only about enough children to replace itself. (2) Could complete data have been collected for *all* the graduates from 1870-1899, it would probably have been found that this aggregation has not replaced itself. It will be recalled that about twenty-five per cent of the alumni are dead. This means that the survivors, to whose families almost exclusively our facts apply, were longer-lived, on the whole, than their deceased colleagues. The longer-lived people have the larger families. Hence the group of alumni we have studied was doubtless somewhat more fecund, in proportion to its size, than the whole alumni body. Therefore, if the former scarcely more than replaced itself, the latter probably did not.*

The writer does not imply that Allegheny College is in any way unique in this respect. Low birth rates seem to be characteristic, as has been mentioned, of college graduates and the "higher" classes of society in general. The showing of the Allegheny College alumni is better than that of graduates of Wellesley, Mount Holyoke, Vassar, Harvard, Yale, and Syracuse. The writer is inclined to believe that the pleasant and wholesome social relationships, fostered by the college authorities, between men and women students at Allegheny, favors matrimony.

*The following suggestion was received from Dr. Sewall Wright of Washington, D. C., after this article went to press:

It is obvious that the parental group under consideration includes not only the college graduates, but also a part of the general population, namely, the wives and husbands of these graduates. Hence, in addition to including in the parental group the unmarried graduates, a certain number of unmarried persons from that section of the population into which the graduates married should have been added to the parental group. The writer knows of no way in which the appropriate number of such single persons from the general population could be computed. However, it is clear for the above reason that the parental group cited in this paper is smaller than it should be. Therefore, it seems likely that the families of Allegheny graduates have fallen even farther short of replacing their section of the population than is indicated in this article.

The situation, from a biological and racial standpoint, at Allegheny College and the other institutions cited, is unsatisfactory. The population of the United States has more than doubled during the period covered by this study. Much of this increase is due to the immigration of stocks of doubtful or inferior worth. The spectacle of the stationary or dwindling old American families of demonstrated capacity, silhouetted against the (until recently) inrushing hordes from southern and eastern Europe, is an ominous spectacle that no intelligent person will ignore.

The ethical aspects of the problem should be considered with the biological. Childless persons and single children are not likely to be habitually cooperative. The "give and take" in a family of five or six persons develops habits of helpfulness that make a better neighbor and citizen. Love of the members of one's family is a channel through which love for mankind in general may easily flow.

Summary

Variations in mental capacity are inherited. In spite of the fact that civilization and progress depend upon a sufficient proportion of unusually intelligent persons, such strains do not appear to be holding their own in our increasing population. This is true of college graduates as far as they have been studied. The birth and marriage rates have remained fairly constant for graduates of Allegheny College (classes of 1870-1899), but the group has probably fallen somewhat short of producing enough children to replace itself.

TABLE 7. *Data concerning families of clergymen.*

Period of graduation	Single		Married		Average age at graduation	Average age at marriage	Childless Marriages		Av. No. children per family
	No.	Per cent	No.	Per cent			No.	Per cent	
1870-1884	1	4.3	22	95.7	24.9	29.5	2	9.1	4.7
1885-1899	1	2.6	37	97.4	26.2	30.8	6	16.2	3.0

TABLE 8. *Comparison of parental group with the computed number of children to reach an age of 20-24 years.*

Number of married man graduates, plus their wives, some of whom are graduates	510
Number of second wives of men graduates	9
Number of single men graduates	36
Number of married women graduates, plus their husbands; women who married men graduates are omitted	54
Number of single women graduates	32
Parental group, total	641
Number of men graduates' children, living and dead; (includes all children both of whose parents are graduates)	698
Number of women graduates' children, living and dead	54
Total children	752
Computed surviving children, age 20 years	591
Computed surviving children, age 21 years	588
Computed surviving children, age 22 years	585
Computed surviving children, age 23 years	582
Computed surviving children, age 24 years	579

TABLE 9. *Comparison of clergymen of parental group with the number of their surviving children 23 years of age.*

Number of married ministerial graduates plus their wives	118
Number of second wives	3
Number of single ministerial graduates	2
Total	123
Number of minister's children, living and dead	216
Computed surviving children, age 23	167

TABLE 10. *Comparison of size of parental group in which the wives are at least 45 years of age, with the number of surviving children 20-24 years old.*

Number of married men graduates, plus their wives, some of whom are graduates	352
Number of second wives of men graduates	7
Number of single men graduates	25
Number of married women graduates (45 years old or older, or deceased), plus their husbands; women who married men graduates are omitted	48
Number of single women graduates	28
Parental group, total	460
Number of men graduates' children, living and dead, (includes all children, both of whose parents were graduates)	493
Number of women graduates' children, living and dead	49
Total children	542
Computed surviving children, age 20 years	426
Computed surviving children, age 21 years	424
Computed surviving children, age 22 years	422
Computed surviving children, age 23 years	420
Computed surviving children, age 24 years	418

A Handbook for Tropical Plant Breeders

HANDBUCH DER LANDWIRTHSCHAFTLICHE PFLANZENZUECHTUNG, by C. FRUWIRTH. Band V., Die Zeuchtung kolonialer Gewaechse. Zweite, gaenzlich neubearbeitete Auflage. Pp. 272. Price, $2.00. Berlin, Verlagsbuchhandlung Paul Parey, 1923.

The first edition (1912) of Dr. Fruwirth's unique and almost indispensible work has been out of print for nine years; only the war and the subsequent difficulty of getting together a new set of collaborators have caused this delay in its reappearance. The present book is rewritten and brought up to date by experts from all parts of the world: American collaborators are H. J. Webber (citrus fruits), O. E. White (castor bean), and G. F. Freeman (cotton). While most of the important colonial products are given attention, one notes some strange omissions, as for instance, the banana and the pineapple. The date palm is dismissed with a perfunctory single page. The volume lacks an index. But despite some imperfections, the book stands alone as a compilation of the most useful data on the breeding of some of the principal crops of the world. Much of the most important work in plant breeding during the next few generations is likely to be done in the hitherto largely untouched field of tropical crops, and Dr. Fruwirth's handbook will probably be the starting point for most of the breeders.—*P. P.*